Demonstration and Driveability Project to Determine the Feasibility of Using E20 as a Motor Fuel

Final Report submitted to
Minnesota Department of Agriculture

by

David Kittelson, Andy Tan, and Darrick Zarling
University of Minnesota, Department of Mechanical Engineering
111 Church Street SE
Minneapolis, MN 55414

Beth Evans, Evans Research Consultants
Carlton H. Jewitt, Consultant, Renewable Fuels Association

October 19, 2007 (IR)

Table of Contents

ABSTRACT

Minnesota Statute 239.791 Subd. 1a requires that on August 30, 2013, gasoline sold in the State of Minnesota shall contain at least 20% denatured ethanol by volume. If on December 31, 2010, however, it is determined that 20% of the State's gasoline volume is ethanol, then this provision expires. If 20% volume replacement is not achieved by 2010, then the 2013 requirement becomes effective provided the United States Environmental Protection Agency (US EPA) certifies E20 by December 31, 2010. In order to use E20 in non-Flex-Fuel vehicles, it will be necessary that the US EPA certify E20 as a motor fuel through a waiver under section 211(f) (4) of the Clean Air Act.

In order for E20 to be certified by the EPA, five main areas of documentation must be presented in the process of application for their consideration: driveability, material compatibility, emissions, exhaust and evaporative emission control systems durability, and health effects.

Three complementary projects were commissioned in pursuit of this waiver: (1) the current project, a yearlong demonstration and driveability project at the University of Minnesota (UMN), Twin Cities; (2) a materials compatibility project that is nearing completion at Minnesota State University, Mankato; and (3) a preliminary emissions study that is nearing completion by the Renewable Fuels Association (RFA). Additional emissions testing, emission systems durability and health effects testing will require more work and will be addressed at the conclusion of these studies.

In pursuit of the EPA waiver, the State of Minnesota contracted the University of Minnesota to conduct a driveability evaluation of a vehicle test fleet consisting of 80 university vehicles, comprising 40 pairs of similar vehicles with similar usage patterns. One of each pair of vehicles was fueled with the baseline fuel for the test program (E0) and the other was fueled with the project test fuel (E20). Vehicle drivers were asked to complete daily log sheets indicating any driveability problems that occurred. These lay driver evaluations were compiled throughout the study along with maintenance and fuel consumption data. In addition, trained vehicle driveability raters were contracted to conduct industry standard driveability tests on a subset of the vehicle fleet, with a test series in each season: fall, winter, spring, and summer.

Although some differences in performance were observed between vehicles fueled by E0 and E20 by both lay drivers and trained raters, the differences were small, inconsistent, and not statistically significant. Minor mechanical failures occurred but they are not believed to be fuel- related. The difference between the fuel consumption of matched pairs of E0 and E20 vehicles was very small and not statistically significant. In summary, no significant differences between paired E0 and E20 vehicles were observed in driveability, reliability, or fuel economy.

I. INTRODUCTION

Minnesota Statute 239.791 Subd. 1a requires that on August 30, 2013, gasoline sold in the State of Minnesota shall contain at least 20% denatured ethanol by volume. If on December 31, 2010, however, it is determined that 20% of the State's gasoline volume is ethanol, then this provision expires. This volume replacement could be accomplished by an average of the increased use of E85 and E10 blends, but that would require a large increase in the use of E85 vehicles. If 20% volume replacement is not achieved by 2010, then the 2013 requirement becomes effective provided the United States Environmental Protection Agency (US EPA) certifies E20 by December 31, 2010. In order to use E20 in non-Flex-Fuel vehicles, it will be necessary that the US EPA certify E20 as a motor fuel through a waiver under section 211(f) (4) of the Clean Air Act.

In pursuit of the EPA waiver, the State of Minnesota contracted the University of Minnesota to conduct a driveability evaluation of a vehicle test fleet consisting of 80 university vehicles, comprising 40 pairs of similar vehicles with similar usage patterns. One of each pair of vehicles was fueled with the baseline fuel for the test program (E0) and the other was fueled with the project test fuel (E20). Vehicle drivers were asked to complete daily log sheets indicating any driveability problems that occurred.

The starting date for the project was initially scheduled for March 15, 2006; however, due to delays in finalizing the contracts, the project was not started until May 24, 2006. The complete driveability study required just over one year to complete.

The underground fuel tanks at the UMN Fleet Services facility were emptied, cleaned, and filled with the two fuels (E0 and E20). The drivers of the 80 test vehicles were issued new fuel keys, or "chips," which gave them access to only the appropriate fuel for their particular vehicle. Fuel usage was electronically monitored.

Drivers were asked to complete a daily vehicle driveability log sheet. The log sheets were collected and reviewed each week. Driver training meetings were scheduled at various times early in the project to explain the project itself and completion of the log sheets. The drivers were requested to attend one of the meetings at a convenient time for them. Instructions, procedures, and definitions were discussed at the training meetings. Appendix A shows the instruction sheet given to the drivers.

In addition to the driveability evaluations by the lay drivers, professional driveability raters evaluated a subset of a nominal twelve pairs of vehicles over four separate seasons.

II. SUMMARY AND CONCLUSIONS

The principal results of the thirteen-month University of Minnesota E20 fleet demonstration and driveability evaluation are listed below. The vehicle test fleet consisted of 80 university vehicles, comprising 40 pairs of similar vehicles with similar usage patterns. One of each pair of vehicles was fueled with the baseline fuel for the test program (E0) and the other was fueled with the project test fuel (E20). Vehicle drivers were asked to complete daily log sheets indicating any driveability problems that occurred. These lay driver evaluations were compiled throughout the study along with maintenance and fuel consumption data. In addition, trained vehicle drivability raters were contracted to conduct industry standard driveability tests on a subset of the vehicle fleet, with a test series in each season: fall, winter, spring, and summer.

- Analysis of vehicle driveability data generated by the lay drivers reveals that seasonal performance differences between E0 and E20 are inconsistent and not statistically significant. All statistical testing is based on the requirement of a 95% confidence level.
- Analysis of vehicle driveability evaluations performed by the trained raters shows that seasonal performance differences between E0 and E20 are not statistically significant at the 95% confidence interval.
- The trained raters' evaluations show that there is not a significant difference in performance between E0 and E20 throughout the year when exposed to the extreme cold and heat of Minnesota weather.
- The trained raters' evaluations also show that both E0 and E20 performed the worst in the winter.
- Study of the maintenance records of the forty E20 test vehicles reveal there to be two instances of vehicle operability failure. In one case, the fuel system pressure regulator failed and, upon inspection, it was determined to be a fairly common hardware-related problem. The other case involved the electronic control unit.
- The properties of the E0 and E20 fuels used in the program were monitored through regular testing. The main properties are summarized below:
    - Ethanol content of the nominal E20 fuels ranged from 18.7 to 22.8 volume % throughout the thirteen-month vehicle driveability study.
    - The driveability index (DI) of the E20 fuels, adjusted for actual ethanol content, ranged from 973 (winter) to 1046 (summer). The DI of the E0 fuels ranged from 1042 (winter) to 1199 (summer). ASTM specifications for Minnesota call for DI maximums of 1200 during winter and 1250 during summer.
    - TVL20s of the E20 fuels ranged from 104°F (winter) to 127°F (summer), whereas the E0 fuels ranged from 106°F (winter) to 142°F (summer). ASTM specifications for Minnesota call for TVL20 minimums of 105°F during winter and 124°F during summer.
    - T50s of the E20 fuels ranged from 155°F (winter) to 159°F (summer), whereas the E0 fuels ranged from 192°F (winter) to 220°F (summer). ASTM specifications for Minnesota call for T50s of 150°F minimum and 230°F maximum during winter; and 170°F minimum and 250°F maximum during summer.

III. TEST VEHICLES

For the test fleet, 40 pairs of vehicles were chosen from UMN Fleet Services. The vehicles were chosen as pairs of the same year, make, and model that would have similar usage patterns.

There were no carbureted vehicles in this program, but hybrids were included. The vehicle model years ranged from 2000 to 2006. Engine displacement ranged from 1.5 to 8.1 liters. Starting odometer reading ranged from 2,271 to 44,753. The fleet consisted of 14 passenger cars and 66 light-duty trucks or vans. Vehicles were manufactured by DaimlerChrysler, Ford, General Motors, and Toyota. A complete description of the 80 vehicles is presented in Appendix B.

IV. TEST FUEL

The study and analysis of fuel characteristics are an integral component of a fuel by vehicle driveability research program. Indeed, vehicle driveability performance is directly related to fuel volatility characteristics. The Minnesota – Renewable Fuels Association E20 Fuel Research Program includes a one-year study of the correlation between vehicle driveability demerits, or lack thereof, fuel volatility measurements and ethanol content. Specifically, fuel volatility characteristics can predict whether or not the fuel will provide optimum vehicle driveability.

The vehicle driveability study utilized two fuels, one containing 0% ethanol and the other fuel containing nominal 20 volume % ethanol. The E0 fuel was commercially available hydrocarbon-only, regular octane grade gasoline. The E20 fuel was comprised of commercially available E10 up-blended with ethanol to E20.

The automotive and petroleum industries have conducted and continue to conduct fuel volatility research programs. Excellent vehicle driveability is demanded by consumers and is the driving force for auto-oil cooperative research. Fuel volatility is defined by a combination of measurements obtained by precise analytical testing. Tests include distillation, vapor pressure, vapor-liquid ratio and driveability index. Complete volatility specifications are detailed in ASTM document D 4814, "Standard Specification for Automotive Spark–Ignition Engine Fuel."[1]

Various portions of the gasoline distillation curve have been correlated with engine performance. For example, vapor pressure and the initial approximately 5% (all percentages are volume based) distilled are related to acceptable cold start, the next 15% distilled is associated with cold driveaway and warm up, the next 35% impacts hot start and hot driveaway, the remaining approximate 45% is associated with higher energy content and fuel economy. A more comprehensive discussion is presented in Chevron Products Company document "Technical Review of Motor Gasolines."[2]

In addition to distillation requirements, there are additional volatility-related specifications. Two of these specifications are adjusted throughout the seasonal changes of the year and are referred to as driveability index and vapor-liquid ratio.

Driveability index is a predictive measurement associated with acceptable cold engine start-up and driveaway at low temperatures. Driveability index (DI) is derived from an empirical mathematical model which incorporates distillation temperatures at which 10%, 50%, and 90% volume are evaporated (distilled). Driveability indices are adjusted seasonally. A fuel possessing a DI less than the seasonal maximums specified within ASTM gasoline specifications would be expected to provide greater assurance of acceptable vehicle cold-start and driveaway.

Vapor-liquid ratio is also adjusted throughout the seasons of the year, and it is a measure of gasoline vaporization at a given temperature. It is commonly expressed as TVL20, the temperature at which the fuel forms twenty volumes of vapor per one volume of liquid. Seasonal TVL20s are also specified within ASTM gasoline specifications. TVL20 is associated with acceptable hot engine start-up and driveaway during hot ambient temperatures. A TVL20 greater than that specified within ASTM gasoline specifications would be expected to provide greater protection against fuel system vapor-lock-type operational problems.

In summary, the more important gasoline volatility characteristics are T10, T50, T90, DI, and TVL20. These characteristics of the test fuels are discussed below. The reader should be aware the preceding discussion does not represent the entire consideration of fuel volatility characteristics and analyses. Rather, it is a snapshot of several of the more important volatility quality measurements of the fuels.

Throughout the nominal one-year vehicle driveability study, the UMN Fleet Services Facility received 24 deliveries of E0 and 10 deliveries of E20. The fuel shipment dates are presented in Table 1, and the ASTM fuel specifications are detailed in Table 2. Tables 3a and 3b present T10, T50, T90, DI, and TVL20 analyses of E0 and E20 fuels as reported by the Minnesota Weights and Measures Laboratory. Tables 4a, 4b, 4c, and 4d present the subject inspections of a number of fuel samples from tankage after drops of the shipments of E20 and E0, both delivered on the same date or very close to the date of the E20 deliveries. Table 4a presents averages of the inspections for the fall of 2006, Table 4b for the winter of 2006/2007, Table 4c for the spring of 2007, and Table 4d for the summer of 2007.

Samples of the fuels used in this program were collected regularly for analysis. Each of the fuels listed in Table 1 were analyzed for the following characteristics: distillation curve, vapor pressure, TLV20, content of ethanol, MTBE and benzene, and density. API gravity and driveability index (DI) were calculated; the former from density, and the latter from the distillation curve. An adjusted DI was calculated for the E20 fuel using the distillation curve and ethanol content. Initially, the fuel analysis did not include the TVL20 measurement. The testing agency, the State of Minnesota Department of Commerce, Weights and Measures Division, did not initially have the equipment for this test and had to purchase and install it. This delayed the TVL20 measurements by about nine months. The backup fuel sample from each of the shipments was retained in dark refrigerated storage for eventual testing; however, those stored samples might have lost some volatility over time.

The distillation curves are plotted in Figures 1 and 2 for E20 and E0 fuels, respectively. Figure 1a shows curves for each of the E20 fuels tested, while Figure 1b shows average curves for summer, Class A and winter, Class D and Class E fuels. Also shown are the ASTM standards for Class A, D, and E fuels. Fuels are required to have distillation temperatures below the standard temperature at 10% (T10) and 90% (T90) evaporated and between temperature limits for 50% evaporated (T50). The E20 fuels shown in Figure 1a all meet T10 and T90 standards, but all the summer fuels fall below the Class A lower T50 limit of 170°F; that is, their midpoint volatility is too high. All the E0 fuels shown in Figure 2a meet these standards.

The detailed results of the fuel analyses are shown in Tables 3a and 3b. Also shown are the ASTM requirements for T50, DI, vapor pressure, and TLV20 corresponding to each delivery date (Class A, C, D, and E fuels). The cells highlighted in cyan indicate results that are out of specification by more than 1% conditions. The samples listed in red in Table 3a were compromised. For sample 33768 (11/22/06), the test started before the testing laboratory was relocated, and most of the sample was lost. For sample 33769, the sample cap came off before testing. The lower part of Table 3a shows the classes of TVL20 for vapor lock protection and the monthly requirements for Minnesota. The TVL20 temperature should not fall below the values indicated; therefore, TVL20s that were higher than specified would be expected to provide greater protection against fuel system vapor-locking – problems.

Examination of Table 3 shows that the T50 values for all the summer E20 fuels fell below ASTM (Class A) specifications. This is also apparent from the plots of Figure 1. Total vapor pressure and Reid vapor pressures of most E0 and E20 samples were above the specification, also indicating excessive fuel volatility for that time of the year. TVL20 values for most of the E20 fuels were borderline, and two samples were below the standard.

Table 3 also shows driveability indices calculated in two ways. The traditional calculation was developed for hydrocarbon-only gasoline and bases the index entirely on the ASTM distillation curve. Here, DI is defined as follows:

$$DI = 1.5*T10 + 3*T50 + 1*T90$$

The addition of ethanol tends to increase the volatility of the fuel and depress T50. To compensate for this, a driveability index has been developed from CRC research programs applicable for ethanol blends up to E10. It is given by:

$$DI = 1.5*T10 + 3*T50 + 1*T90 + 2.403*vol\%EtOH$$

Although the above-modified DI equation has not been validated for ethanol blends higher than E10, it should still be better than the hydrocarbon-only DI for the E20 blends. For the E0 blends, the DI has been calculated utilizing the hydrocarbon-only DI equation. For the E20 fuels, DIs have been calculated utilizing both of the above-described driveability index equations. The reported driveability indices for the E20 fuels which contain the ethanol term are calculated utilizing the modified DI equation and the actual ethanol content of the E20 fuels. These are shown in Table 3. It is recommended that DI for Minnesota not exceed 1250 in warm weather and 1200 in cold weather. All fuels tested meet these standards.

Table 3 also shows the ethanol and benzene content of the fuels. The E0 fuels were ethanol-free, and the E20 fuels ranged from 18.7 to 22.8 volume % ethanol. Benzene content of the E0 fuels ranged from 0.7 to 2.2 volume %, and for the E20 fuels from 0.8 to 1.1 volume %.

Caution must be exercised to fully understand the discussion of fuel analyses. The E0 and E20 fuel samples tested and recorded in Tables 3 and 4 represent the product of commingling the fresh gasoline pumped into the underground storage tank with each new fuel delivery plus the gasoline remaining in the tank from previous loads. Each tank was then sampled through the dispenser hose after the commingled fuel had been allowed to purge the dispensing system of the residual fuel as it existed before the delivery. This commingled fuel as tested then represents the fuel that would be used in the vehicles subsequent to each delivery. The commingled fuel, therefore, would not necessarily be expected to meet specifications as would the fuel dropped fresh at each delivery event. UMN Fleet Services' efforts to minimize commingling by way of inventory control were persistent throughout the study so that the vehicles were operating to that extent possible on appropriate seasonal volatility fuels. These characteristics might suggest hot-weather driveability problems not necessarily related to the ethanol content, but to the trailing volatility of the gasoline portion of the fuel caused by the relative infrequent deliveries of the E20.

The effects of the above described commingling are revealed upon study of the fuel volatility characteristics. For example, the significant drop in vapor pressure of the E20 fuel following the 3/28/07 fuel delivery should be noted. It is this fuel which was in the test vehicles during the trained raters' driveability evaluations which occurred 4/14/07. Attention is also directed to the volatility characteristics of the E20 fuel evaluated by the trained raters during the summer and yet represents the higher vapor pressure, cold-weather volatility fuel which was delivered during May. The preceding represents but a few examples of the importance of sampling and analyzing the E0 and E20 fuels exactly representative of the respective fuel dispensed into the test vehicles and as it relates to analysis of fuel by vehicle driveability analyses.

A study of the fuel inspections presented in Tables 4a, 4b, 4c, and 4d reveals ASTM specification failures for the E20 fuels as measured by T50. Such was not unexpected. The primary technical concern was related to a spark-ignited automotive motor fuel containing 20 volume % of a single boiling point component, ethanol. It was known the continuum of a hydrocarbon-only gasoline distillation curve is interrupted with 10 volume % ethanol. The continuum would be expected to be disrupted to a greater degree with 20 volume % ethanol. This pronounced disruption occurs beginning approximately at the T20 point up to and including the T50 point. The corresponding "flattening" of the distillation curve occurs beginning at approximately 125°F up to approximately 160 – 170°F. The ethanol (boiling point 173°F) thus significantly depresses T50. The depression of T50 for the E20 fuels is readily apparent as graphically presented in the distillation curves contained in Figures 1a and 1b compared to the curves for the E0 fuels shown in Figures 2a and 2b.

V. TEST SITE

The lay drivers went about their normal routines while driving the test vehicles such that there was no particular test site for that portion of the program. Much of the normal vehicle operation took place on the University of Minnesota's Minneapolis and St. Paul campuses, with low miles and frequent engine starts and stops. Several of the vehicles involved were part of UMN Fleet Services' rental pool and could have been driven essentially anywhere. The temperatures recorded on Figures 5a, b, c and d were measured inside city limits at the Minneapolis/St. Paul campus of the University of Minnesota where most of the lay drivers logged their miles.

For the evaluations by the trained raters, an acceptable "test track" was required. A closed course was necessary where the 20 vehicles could be parked overnight safely, and the test track needed to be immediately accessible to the parked vehicles to allow cold engine driveability to be evaluated. The initial test site used for the fall rating session was located in Arden Hills, Minnesota, and was being used by the Minnesota Department of Transportation (MnDOT) for training, along with Ramsey County and others. The property was owned by the Minnesota National Guard. There was a straight section of paved roadway that is slightly over a half-mile long. It was rougher than desired, but had no significant potholes or other characteristics that significantly interfered with the testing.

Because of the rough pavement at the MnDOT facility, several alternate test sites were investigated, and the UMN's UMORE campus in Rosemount, Minnesota, was selected and used for the final three seasonal evaluations by the trained raters. Since the trained rater evaluations were located at test sites in the suburbs well outside the city limits, portable temperature recording devices were used to record local ambient temperatures during the overnight soak periods and the driveability test maneuvers.

VI. TEST PROGRAM

A. Test Procedure

The procedures for the lay drivers were explained during the drivers' training meetings conducted but weeks after the test fuels were introduced into the vehicles. Four different meeting times were scheduled so that drivers could choose the most convenient time to attend the meeting. Terminologies and definitions of malfunctions were based upon CRC Report Numbers 6383 and 6484, but were slightly modified to make it easier for the drivers to complete the log sheets and to avoid putting drivers at risk in traffic. During the training meetings, all the drivers were asked if they had noticed any change in the operation of their vehicles compared to the normal fuel (E10) they had used. Drivers did not report noticing any difference in vehicle performance.

For the trained rater evaluations, the test techniques were used as described in the CRC reports3,4. This included an overnight cold soak for the vehicles during the fall, winter, and spring sessions, and a pre-test vehicle warm-up and three hot soaks during the summer testing.

B. Fueling

There is an automatic fueling system at UMN Fleet Services that allowed the drivers to fill with only the assigned fuel for the vehicles they were using. This ensured that no vehicle could be filled with a different kind of fuel other than the rental vehicles driven to another location and requiring an emergency fueling.

C. Log Sheet

Feedback from the lay drivers was collected, reviewed, and entered into the database weekly. This included the date, odometer reading, idle quality, and driving quality for both cold and warmed-up conditions. Daily climate data from the UMN St. Paul Campus Climatological Observatory website were also entered.

VII. DISCUSSION OF RESULTS

A. Lay Driver Data Analysis

Table 5 shows a sample log sheet that the lay drivers were asked to complete. The log sheets were collected and reviewed weekly. Driver training meetings were scheduled at several times early in the project to explain the project and completion of the log sheets. The drivers were requested to attend one of the meetings at a convenient time for them. Instructions, procedures, and definitions were discussed at the training meetings. Approximately half of the drivers attended a training meeting. During the training meetings, all the drivers were asked if they noticed any change in the operation of their vehicles during the previous month, especially those who had filled with "test" fuel (E20). None of the drivers reported any initial driveability issues.

Table 6 shows the frequency of the lay driver feedback measured on a daily basis. Because some of the vehicles were being operated seven days a week (although by different drivers), the number of responses was divided by the number of days assuming full seven-day weeks in the specific season. The lay driver survey covered thirteen months; thus, the extra month of testing in the summer of 2007 was added to the summer of 2006 and presented in the summer category. This method was used throughout the tables and figures for the lay driver data. The lay driver response rate for completing the log sheets was disappointing throughout the thirteen-month vehicle driveability study, averaging 30 – 40%.

Table 7 details the responses to the driver surveys submitted through the middle of August 2007. Many of the vehicles for which events had been reported earlier in the program did not report any events after about the middle of the fall season, while some other drivers started turning in their log sheets later in the program. In addition, there were drivers submitting their log sheet for a group of weeks at one time, instead of on a weekly basis. Table 8 summarizes the lay driver response rates for completing the log sheets. Results are shown only for vehicles for which both vehicles in the vehicle pair have submitted responses during a given season. The overall fractional rates for the thirteen-month study were disappointingly low, 32% and 39% for E0 and E20 vehicles, respectively.

The results of the driveability evaluation log sheets were converted to a numerical scoring system to allow quantitative analysis of the results. Table 9 shows the scoring values used, which are the same values for both a cold and warm engine. All the dates were categorized seasonally to calculate the averages and 95% confidence intervals: summer (July through September 2006 and 2007); fall (October through December 2006); winter (January through March 2007); and spring (April through June 2007). Table 10 presents the results after they were converted to the numerical scoring system. Statistical results have been calculated in two ways. In the first, all of the reported demerits for a given season and fuel are used. This is the count-weighted method. This method, however, may be biased in that the drivers of some vehicles reported the same problems over and over, while for other vehicles which may have had similar problems, reports were not submitted as often. Thus, vehicles in which the drivers were more diligent in completing reports will be more heavily weighted. In the second method, the average demerits for each vehicle are calculated and statistics are based upon performance of individual vehicles. This is the vehicle-weighted method. Table 10a and Figure 3 show the averages and 95% confidence intervals based on count-weighting, while Table 10b and Figure 4 show the corresponding statistics using the vehicle-weighted method. Table 11 lists individual vehicle averages, as well as the number of reports including those turned in, but reporting no events.

Table 10 and Figures 3 and 4 show that seasonal performance differences between E0 and E20 determined by the lay driver surveys are inconsistent and, except for two cases, not statistically significant. For example, on a vehicle-weighted basis, E0 performs less well than E20 during the fall and winter seasons, while the reverse is true if the count-weighted basis is used. This illustrates the limitations of using evaluations of drivers not specifically trained in driveability evaluation. On the other hand, the inconsistency and lack of statistical significance suggests that differences in performance of the two fuels were not great. There was no "smoking gun." It is still useful, however, to consider individual driveability events.

B. Driveability Events

The overall response rates are summarized in Table 8. The total number of vehicle drivability events reported is 1,342 for E0 and 1,355 for E20, with more events reported for E0 during the spring, summer, and winter, and more for E20 during the fall. None of the vehicles used an engine block heater during the project. Figure 5 shows daily temperatures for these periods to help interpret the results.

Throughout the project, only two vehicles had a check-engine light illuminate. One was Vehicle License Number 911297, which ran on E20. The fuel pressure regulator failed; however, the shop manager does not believe this was due to the fuel being used. He indicated this is a common hardware failure for that specific make and model. The other vehicle was License Number 914209 which also ran on E20. It appears that mice had eaten the wiring around the Electronic Control Unit (ECU).

C. Trained Rater Evaluation

To assist in scientifically validating the test, trained driveability raters evaluated a subset of a nominal twelve pairs of vehicles over four separate seasons. Although the program began in the summer of 2006, the first test session with the trained raters was held in the fall, on October 21, 2006. The winter test session was conducted on January 20, 2007, the spring test on April 14, 2007, and the summer session took place on July 28-29, 2007.

The trained rater evaluations used industry-recognized procedures and practices developed and used by the Coordinating Research Council (CRC). It must be clearly understood; however, that CRC is not associated with the Minnesota – Renewable Fuels Association (MN-RFA) E20 Research Program, has provided no funding, and has not reviewed or endorsed the MN-RFA E20 Research Program.

Vehicle driveability evaluations were performed by two trained raters using a cold-start and warm-up driveability procedure3 during the fall, winter, and spring testing. A hot-start hot-fuel-handling procedure4 was used during the summer testing. Because hot-fuel-handling testing requires long soak times within the test, two days were needed for the summer testing. The trained raters are knowledgeable and experienced with vehicle driveability testing.

Of the nominal twelve pairs of vehicles assigned for driveability testing, one of each pair was operated on E0 and the other was operated on E20. Each vehicle was assigned to the same rater throughout four seasonal tests. Because of the logistical difficulties in making these same vehicles available for all four testing sessions, there were some substitutions and omissions during each testing session; however, there is a core set of paired vehicles that were tested in all four testing sessions. Three vehicles that were tested during the fall session were sold and replaced with vehicles of the same make and model. The replacement vehicles had already been part of the overall 80-vehicle test fleet. The list of vehicles tested and in which of the four sessions they were evaluated is presented in Table 12. Fuel samples for analysis of ethanol content were taken from the fuel tanks of randomly selected vehicles during the spring and summer trained raters' evaluations. The results of these analysis are listed in Tables 13 and 14.

The timing of the fall session was scheduled to take advantage of ambient temperatures in the 30°F – 40°F range since this can potentially be a critical calibration range for vehicles. Somewhere in this ambient temperature range, vehicles typically adjust their calibration from being enriched to operate in cold weather to operating in a leaner condition for warmer weather. This 30°F – 40°F range is often called a "shoulder temperature," because of its position on the edge of both types of calibration. The fall testing all took place within a tight optimal 34°F – 36°F band.

The goal for scheduling the winter session was the coldest weather of the season. This typically occurs sometime between the second weekend of January and the first weekend of February. On the date of the winter testing session (January 20, 2007), the temperature ideally reached the single digits below zero °F overnight, and the test finished at +7°F.

The date for the spring session was selected due to the vapor pressure regulations, rather than weather. Per Minnesota ASTM guidelines, the vapor pressure must be lower for spring (a maximum of 13.5 psi) than it is for winter (a maximum of 15 psi). This transition occurs during the month of March. This relatively small vapor pressure reduction is then followed in April by the spring to summer transition, resulting in a maximum of 9.0 psi. Thus, the spring testing session was scheduled for April 14, 2007, when the intermediate vapor pressure was available. In order to ensure that the desired fuel with the proper vapor pressure characteristics was used in the vehicles before and during the trained rater evaluation, fuel storage tank levels were closely monitored, and shipments were ordered at the appropriate times.

The summer session was scheduled for the warmest weather of the year, which typically occurs beginning the second half of July to early August in Minnesota. All vehicle tests on July 29th were performed in the ambient temperature range of 90°F – 98°F. All testing on July 30th was conducted in the ambient temperature range of 87°F - 100°F. A single vehicle evaluation occurred at 87°F when the sun was temporarily blocked by several clouds. All remaining testing on July 30th was conducted within the ambient temperature range of 93°F – 100°F.

The cold-start and warm-up driveability procedure that was used is presented in detail in Reference 3. The procedure consists of a series of light, moderate, and wide-open-throttle maneuvers mixed with idles to obtain as many evaluations as possible of driveability in a cold engine at cold temperatures. Malfunctions such as hard-starting, idle roughness, hesitation, stumble, surge, backfire, and stalls are recorded. Severity levels are evaluated as trace, moderate, heavy, or extreme.

The hot-fuel-handling procedure that was used is detailed in Reference 4. Immediately prior to testing, the vehicle is driven for 20 miles during which the vehicle is operated at 15 mph, 25 mph, 35 mph, 45 mph, and 55 mph. The vehicle is then immediately parked in a roofless soak shed for 20 minutes with the ignition off. This roofless soak shed is intended to simulate a parking lot condition with very little air flow around the vehicle and the sun beating down upon it. The engine is then re-started after the 20-minute engine-off soak, and the vehicle is accelerated at wide-open-throttle to 35 mph. Malfunctions such as hard-starting, idle roughness, hesitation, stumble, surge, backfire, and stalls are recorded. Severity levels are evaluated as trace, moderate, heavy, or extreme. The vehicle is then parked in the roofless soak shed with the engine on for 20 minutes, followed by a light-throttle acceleration during which malfunctions are evaluated. After another engine-off 20-minute soak, the vehicle is re-started and accelerated at light-throttle, during which malfunctions are evaluated.

The data for both procedures are quantified by numerical demerits, and the summary score for each vehicle/fuel test is calculated as total weighted demerits (TWDs), where low TWDs represent better vehicle driveability, and high TWDs represent poorer vehicle driveability performance. Typically, 15 – 20 TWDs are considered to be experimental noise in the data, with levels above that considered to legitimately distinguish between the fuels. TWDs are often reported as a log transform, log (TWD+1), as this provides a more normal data set. Natural log transform minimizes the skew associated with extremely low and extremely high TWDs by presentation of an exponential function in a linear fashion. The "TWD+1" eliminates the problem of taking the natural log transform if a vehicle has zero TWDs.

The average log (TWD+1) was the highest for the winter rating session, as expected under the cold-temperature conditions. Figures 6a and 6b summarize the results of the driveability evaluations performed by the trained raters during the fall, winter, spring, and summer. Figure 6a plots log (TWD+1) averages, while Figures 6b plots the linear TWD averages. The error bars plotted in Figure 6 are the 95% confidence intervals. Average demerits and confidence intervals are also tabulated in Table 12. Statistical tests were conducted on seasonal averages. These tests showed that none of the seasonal differences between fuels was significant at a 95% confidence level. All averages and confidence intervals are based on vehicle pairs. If one vehicle of a pair was missing in a given season, the other was excluded from the statistics. Figures 7a, 7b, 7c, and 7d show individual vehicle TWD scores for summer, fall, winter, and spring, respectively.

A review of the raw data for all four test seasons reveals that the fleet operated satisfactorily on both fuels. Relatively few objectionable malfunctions were detected, and there were no obvious differences between the fuels. The highest raw demerit scores for the fleet occurred in the winter which, as mentioned above, is not unexpected.

During the fall test session, the TWDs of all but one vehicle fell within the data noise range if data noise is defined as 20 TWDs or less. The one observation above the experimental noise level is a vehicle fueled with E0. Almost all malfunctions, with the exception of idle quality, would not be noticeable to average drivers. By definition, virtually all of the maneuvering malfunctions rated would only be noticeable to a trained rater. There were multiple instances in which degraded idle quality would be noticeable to the average driver; however, these instances were split between the vehicles fueled with E0 (42% of the instances) and those fueled with E20 (58% of the instances).

In the winter test session, there were about 35% of the observations that fell within the data noise level, as defined by 20 TWDs or less. There were maneuvering malfunctions with both the E0 and E20 fuels that would be noticeable to the average driver. As in the fall evaluations, the idle quality is the predominant noticeable malfunction. In the winter testing, there were considerably more instances of noticeable degraded idle quality than in the fall, and the vehicles fueled with E20 had degraded idle quality more often than those fueled with E0. Of the total observations of noticeable degraded idle quality, 62% were from vehicles fueled with E20, and 38% were from vehicles fueled with E0. The overall performance of the entire test fleet was poorer than the fall evaluations, but there was no clear evidence other than idle quality that one fuel performed better than the other. The overall TWDs do not indicate a performance trend of one fuel versus the other.

In the spring test session, there were about 25% of the observations that fell within the data noise level, as defined by 20 TWDs or less. Idle quality was the predominant source of noticeable malfunctions, although there were some maneuvering malfunctions that would be noticeable to average drivers. The maneuvering malfunctions that would be noticeable to the average driver were fairly evenly split between the two fuels. The instances of noticeable degraded idle quality were evenly split between the two fuels: 48% for E0, and 52% for E20. Noticeable degraded idle quality occurred more frequently than in the fall session, but considerably less frequently than in the winter. In four pairs of the vehicles, the vehicles fueled with E0 performed poorer than the vehicles fueled with E20. In one pair, the vehicle fueled with E20 performed poorer than the vehicle fueled E0. In that one case, the results from the spring evaluations were a reverse from the winter evaluations, but they confirmed the fall results with that pair of vehicles. In some cases, the spring results for paired vehicles were similar to the fall findings, and in some cases, they were similar to the results seen in winter.

In the summer test session, there were about 62% of the observations that fell within the data noise level, as defined by 20 TWDs or less. While idle quality contributed heavily to the malfunctions that would be noticeable to average drivers, there were some occurrences of maneuvering malfunctions that would be noticeable to average drivers. The noticeable maneuvering malfunctions were split evenly (50% each) between E0 and E20. In fact, all maneuvering malfunctions, whether noticeable to the average driver by definition or not, were split almost evenly between the two fuels (49% for E0, and 51% for E20). All the degraded idle quality recorded, whether noticeable to the average driver by definition or not, was split evenly between the two fuels: 49% for E0, and 51% for E20. Of the degraded idle quality noticeable to the average driver, 47% belonged to E0, while 53% belonged to E20.

D. Fuel Economy Measurements

This study was not designed to examine fuel economy. For such a study, careful matching of driving conditions and driving patterns is necessary; however, data on fuel consumption and miles driven were available from fleet headquarters. It was decided to present these data not because they are useful for comparing E0 and E20 (conditions were not well enough matched for that), but rather because they give insights into fuel use by a university fleet in a northern climate.

Table 15 lists the average fuel economy observed for the entire thirteen-month study for each of the test vehicles. Two of the vehicles were sold, leading to unmatched pairs. Consequently, neither vehicle in such pairs was considered in the averages. The average fuel economy for the test fleet over the course of the project was relatively low: 11.9 mpg for the vehicles operating on E0, and 11.8 mpg for the vehicles operating on E20. This represents a 0.6% decrease in average fuel economy for the E20 vehicles. If the difference in fuel economy of individual pairs of vehicles is averaged, however, fuel economy is 1.7% higher for the E20 vehicles; although the 95% confidence interval for the paired fuel economy changes is +/- 6.6%. Thus, neither of these results is statistically significant. Further analysis of the data in Table 15 reveals that the results for two of the vehicle pairs can be considered outliers. In this case, outliers are defined as results that are more than two standard deviations from the mean. The outliers are highlighted in yellow. When these outliers are removed, the E20 vehicles show an average fuel economy decrease of 1.4%. Energy content per gallon of E20 is 6.5% than that of E0, so all of these results would be surprising in a controlled fuel economy study. This is not that sort of a study; the statistical uncertainty is large, and the driving patterns were not matched. These results suggest, however, that although not quite at a 95% level, the fuel economy loss with E20 might not be as large as the decrease in energy content per gallon.

None of the reservations above apply to overall fleet fuel economy figures. According to the US EPA's fuel economy website5, the average city fuel economy for late model pickups and vans is about 15 mpg. The university fleet contains many heavy pickups and vans operating in a start/stop driving cycle and in a cold climate, so that the 12-mpg average is not unexpected. The smaller and hybrid vehicles in the fleet delivered the best fuel economy, while the large heavy-duty pickups delivered the worst. Clearly, downsizing and additional use of hybrids, where the application allows, should be encouraged.

Reductions of petroleum consumption and of emissions of global greenhouse gases are primary drivers for the introduction and expanded use of ethanol, biodiesel, and other renewable fuels. Gains associated with these renewable fuels will be further enhanced if these fuels are used in more fuel-efficient vehicles.

VIII. ACKNOWLEDGEMENTS

The University of Minnesota Mechanical Engineering Department wishes to thank the following organizations and individuals who helped make this project possible:

- The Council of Great Lakes Governors
- The Minnesota Corn Research and Promotion Council
- The Minnesota Department of Agriculture
- The Renewable Fuels Association
- Peter Bouley of the University of Minnesota Climatological Observatory
- Art Dunn of the Minnesota Pollution Control Agency
- Steven Harrington, Assistant Director of the Minnesota Department of Commerce, Weights and Measures Division
- Gene Im, Supervisor of the University of Minnesota's UMore Park
- Harold "Archie" Archibald, Trained Rater
- William Roberts of the University of Minnesota Fleet Services and his staff
- University of Minnesota lay drivers who completed the vehicle driveability evaluation log sheets
- University of Minnesota departments that allowed the use of their vehicles for the purposes of the test program
- Student volunteers who helped with the transportation of vehicles between the University of Minnesota Fleet Services facility and the staging areas for the seasonal trained rater evaluations

IX. REFERENCES

1) ASTM document D 4814, "Standard Specification for Automotive Spark–Ignition Engine Fuel."
2) Chevron Products Company document, "Technical Review of Motor Gasolines."
3) Coordinating Research Council, Inc., 2003 CRC Intermediate-Temperature Volatility Program, CRC Report No. 638, February 2004.
4) Coordinating Research Council, Inc., 2006 CRC Hot-Fuel-Handling Program, CRC Report No. 648, January 2007.
5) http://www.epa.gov/otaq/cert/mpg/fetrends/420r07008.pdf
6) Ethanol RFA Website - http://www.ethanolrfa.org/industry/statistics/

APPENDIX A

DAILY LOG SHEET PROCEDURES

1. Write down your '**LICENSE PLATE #**' (or vehicle#), '**MONTH**' and '**DATE**' (Mondays's date of the week).

   NOTE: You could leave the temperature → blank. Write it down if known.

2. Fill in the '**ODOMETER READING**' daily.

   NOTE: *Cold engine* means vehicle that has not been USED for more than 6 hours. And, only valid for about 10 minutes from the *first second of idle*. The rest of the day you will have *warm engine*. In short, most of you will only have 1 cold engine and many warm engine of at least 1.

3. Turn key to *on* position for 2 seconds, meanwhile, turn on defrost and fan in *low* position. Then, start up the engine and record the time it takes you to crank up the engine on the '**START TIME (SEC)**' with 5 seconds max.

4. There may be a total of 3 attempts recorded. When the engine fails, give 5 seconds interval between each attempt. After the 3rd unsuccessful attempt, turn the key to off position before attempting to restart. Once the engine start, record the '**# ATTEMPTS**'

5. Let the engine run on idle while transmission is on park or neutral for 5 seconds. Record the idle quality in '**IDLE QUALITY (P/N)**'. G=Good; S=Stall; 1-2-3 = measure of quality with 3 being the worst.

6. Next, step on the brake and shift the transmission to drive. Let the engine idle in that position for 5 seconds. Record the idle quality in '**IDLE QUALITY (D)**'. G=Good; S=Stall; 1-2-3 = measure of quality with 3 being the worst.

7. Record all abnormal driving behavior in the engine '**DRIVEAWAY**'. Cold engine only applicable for the 1st 10 minutes. Anything beyond the 1st 10 minutes of the day will fall to warm engine. If everything is normal, there is a '**NORMAL**' box and please put a check mark.

Please fill the log sheet up accurately and daily. Mostly when it comes to abnormalities. Use pump #1, #2 or #6 at Como facility for test vehicles. Don't fill up your vehicle elsewhere unless you are far from base and running out of fuel. Fuels from other sources may be quite different from the test fuels. If it is necessary to obtain fuel elsewhere only take enough to get you back to base. Report incorrect fueling immediately.

APPENDIX B

Category	Equip #	Fuel	Class	Year	Make	Model	Engine Configuration	Pairs	VIN #	License #	Milage as 3/1/06
Compact Car	2320	E-20	CSCM	2001	Ford	Focus	Zetec I4 - 2 liter DOHC 130 HP	A	1FAFP383X1W130204	907395	22,100
Compact Car	2302	E-0	CSCM	2001	Ford	Focus	Zetec I4 - 2 liter DOHC 130 HP	A	1FAFP38311W130203	907376	21,150
Mini Cargo Van	21402	E-20	VMC	2002	Dodge	Ram1500	5.2 liter V8 - MPI	AA	2B7HB11YX2K107355	911051	44,753
Mini Cargo Van	21401	E-0	VMC	2002	Dodge	Ram1500	5.2 liter V8 - MPI	AA	2B7HB11Y12K107356	911086	26,177
Compact Car	51047	E-20	CSCM	2005	Toyota	Prius	INZ-FXE	B	JTDKB20UX53053215	920119	24,943
Compact Car	51046	E-0	CSCM	2005	Toyota	Prius	INZ-FXE	B	JTDKB20U757019600	920120	25,221
Mini Cargo Van	22403	E-0	VMC	2002	Dodge	Ram1500	4.3 L - V6 (code "X")	BB	2B7HB11X92K107354	911065	7,264
Mini Cargo Van	22404	E-20	VMC	2002	Dodge	Ram1500	4.3 L - V6 (code "X")	BB	2B7HB11X32K112047	911233	23,437
Compact Car	51059	E-20	CSCM	2005	Chevrolet	Malibu	"LV6" - I4 - 1.8 liter. - MFI	C	1G1ZS52895F301008	920143	27,125
Compact Car	51058	E-0	CSCM	2005	Chevrolet	Malibu	"LV6" - I4 - 1.8 liter. - MFI	C	1G1ZS52875F302156	920142	27,881
Mini Cargo Van	42405	E-0	VMC	2004	Chevrolet	Astro	4.3 L - V6 (code "X")	CC	1GCDM19X24B104883	916330	27,424
Mini Cargo Van	42406	E-20	VMC	2004	Chevrolet	Astro	4.3 L - V6 (code "X")	CC	1GCDM19X64B106037	916332	30,252
Full Size Car	51085	E-0	CSFL	2005	Chevrolet	Impala	Essex 4 liter SOHC Gasoline 207-210	D	2G1WF52E159375674	920145	22,587
Full Size Car	51086	E-20	CSFL	2005	Chevrolet	Impala	Essex 4 liter SOHC Gasoline 207-210	D	2G1WF52E759347121	920121	29,029
Mini Cargo Van	52402	E-0	VMC	2005	Chevrolet	Astro	4.3 L - V6 (code "X")	DD	1GCDM19X95B105501	918510	6,105
Mini Cargo Van	52403	E-20	VMC	2005	Chevrolet	Astro	4.3 L - V6 (code "X")	DD	1GCDM19X35B105557	918512	7,395
Squad Car	53096	E-0	CSSQ	2005	Ford	Crown Victoria	Modular V8 - 4.6 L SOHC 220-235 HP	E	2FAHP71W25X121430	51	30,783
Squad Car	53097	E-20	CSSQ	2005	Ford	Crown Victoria	Modular V8 - 4.6 L SOHC 220-235 HP	E	2FAHP71W45X121431	52	28,531
One Ton Extended Cargo Van	2464	E-0	VOEC	2000	Ford	E350	Triton V8 - 4.6 L SOHC-EFI (W) 225-239HP	EE	1FTSS34LXYHB80450	905945	13,467
One Ton Extended Cargo Van	2465	E-20	VOEC	2000	Ford	E350	Triton V8 - 4.6 L SOHC-EFI (W) 225-239HP	EE	1FTSS34L3YHB73517	905943	16,136
Compact Wagon	22021	E-20	CWCM	2003	Ford	Focus	Zetec I4 - 2 liter DOHC 130 HP	F	1FAFP36312W130254	911225	30,722
Compact Wagon	22020	E-0	CWCM	2003	Ford	Focus	Zetec I4 - 2 liter DOHC 130 HP	F	1FAFP363X2W130253	911099	10,280
One Ton Extended Cargo Van	2477	E-0	VOEC	2001	Chevrolet	Express 3500	6.0 liter - V8	FF	1GCHG39R011145357	907402	16,770
One Ton Extended Cargo Van	2478	E-20	VOEC	2001	Chevrolet	Express 3500	6.0 liter - V8	FF	1GCHG39R111145285	907401	16,159
Compact Wagon	32034	E-20	CWCM	2003	Ford	Focus	Zetec I4 - 2 liter DOHC 130 HP	G	1FAFP363X3W119030	914204	9,983
Compact Wagon	32033	E-0	CWCM	2003	Ford	Focus	Zetec I4 - 2 liter DOHC 130 HP	G	1FAFP36333W119029	914202	18,063
3/4 Ton Cargo Van	2539	E-20	VTC	2000	Chevrolet	Express	5.7 liter - V8	GG	1GCGG25R3Y1151188	903840	44,097
3/4 Ton Cargo Van	2535	E-0	VTC	2000	Chevrolet	Express	5.7 liter - V8	GG	1GCGG25R5Y1152407	911252	20,326
4X2 Cab & Chassis with misc body	32644	E-0	LCC2	2003	Ford	F350	Triton V10 - 6.8L Gasoline SOHC/EFI 305-310 HP	H	1FDWW36S03EA42559	914210	15,024
4X2 Cab & Chassis with misc body	32674	E-20	LCC2	2003	Ford	F450	Triton V10 - 6.8L Gasoline SOHC/EFI 305-310 HP	H	1FDXF47S63EA42561	914209	15,811
3/4 Ton Cargo Van	2479	E-0	VTC	2001	Ford	E250	Triton V8 - 4.6 L SOHC-EFI (W) 225-239HP	HH	1FTNE24L91HA49711	908468	12,826
3/4 Ton Cargo Van	2480	E-20	VTC	2001	Ford	E250	Triton V8 - 5.4 L. SOHC/EFI 250-260 HP	HH	1FTNE24L41HA18074	908685	13,543
Mini 4X2 Pick-Up	52500	E-0	LM2	2005	Ford	Ranger	Intec V8 - 5.4 L SOHC (E)	I	1FTYR10D25PA19505	919310	2,271
Mini 4X2 Pick-Up	52501	E-20	LM2	2005	Ford	Ranger	Intec V8 - 5.4 L SOHC (E)	I	1FTYR10D45PA19506	919309	2,631
3/4 Ton Cargo Van	2482	E-20	VTC	2001	Ford	E250	Triton V8 - 5.4 L. SOHC/EFI 250-260 HP	II	1FTNE24L01HA44879	908467	22,760
3/4 Ton Cargo Van	2481	E-0	VTC	2001	Ford	E250	Triton V8 - 4.6 L SOHC-EFI (W) 225-239HP	II	1FTNE24L01HA49712	908684	9,798
Mini 4X2 Pick-Up	52502	E-0	LM2	2005	Ford	Ranger	Intec V8 - 5.4 L SOHC (E)	J	1FTYR10D65PA19507	918524	23,504
Mini 4X2 Pick-Up	52503	E-20	LM2	2005	Ford	Ranger	Intec V8 - 5.4 L SOHC (E)	J	1FTYR10D85PA19508	918518	3,202
3/4 Ton Extended Cargo Van	2501	E-20	VTEC	2001	Ford	E250	Triton V8 - 5.4 L. SOHC/EFI 250-260 HP	JJ	1FTNS24L51HA18075	907341	13,740
3/4 Ton Extended Cargo Van	2470	E-0	VTEC	2001	Ford	E250	Triton V8 - 5.4 L. SOHC/EFI 250-260 HP	JJ	1FTNS24L11HA17473	907342	26,744
Mini Supercab 4X4 Pick-Up	33542	E-0	LMS4	2003	Dodge	Dakota	3.9 liter V6 MPI	K	1D7HG42XX3S228859	914228	14,818
Mini Supercab 4X4 Pick-Up	33543	E-20	LMS4	2003	Dodge	Dakota	3.9 liter V6 MPI	K	1D7HG42X63S228860	914226	20,211
3/4 Ton Extended Cargo Van	22472	E-20	VTEC	2002	Ford	E250	Triton V8 - 5.4 L. SOHC/EFI 250-260 HP	KK	1FTNS24L92HA20672	909215	35,839
3/4 Ton Extended Cargo Van	22471	E-0	VTEC	2002	Ford	E250	Triton V8 - 5.4 L. SOHC/EFI 250-260 HP	KK	1FTNS24L72HA20671	909216	36,196

APPENDIX B

Category	Equip #	Fuel	Class	Year	Make	Model	Engine Configuration	Pairs	VIN #	License #	Milage as 3/1/06
3/4 Ton 4X4 Pick-Up	32574	E-0	LT4	2003	Ford	F250	Triton V8 - 5.4 L, SOHC/EFI 250-260 HP	L	1FTNF21L43EA65966	914206	8,124
3/4 Ton 4X4 Pick-Up	32575	E-20	LT4	2003	Ford	F250	Triton V8 - 5.4 L, SOHC/EFI 250-260 HP	L	1FTNF21L63EA65967	913339	11,105
12 Passanger Full Size Van	61266	E-20	PF12	2006	Chevrolet	Express	6.0 L - V8	LL	1GAHG35U161131011	921912	4,674
12 Passanger Full Size Van	61265	E-0	PF12	2006	Chevrolet	Express	6.0 L - V8	LL	1GAHG35U641129737	921911	3,474
3/4 Ton 4X4 Pick-Up	62571	E-20	LT4	2006	Chevrolet	K2500	6.0 liter - V8	M	1GCHK24U66E132567	922079	3,991
3/4 Ton 4X4 Pick-Up	62570	E-0	LT4	2006	Chevrolet	K2500	6.0 liter - V8	M	1GCHK24U36E135281	922080	2,635
15 Passanger Full Size Van	41289	E-20	PF15	2004	Chevrolet	Express 3500	6.0 liter - V8	MM	1GAHG39UX41197435	917503	38,732
15 Passanger Full Size Van	41288	E-0	PF15	2004	Chevrolet	Express 3500	6.0 liter - V8	MM	1GAHG39U441197379	916370	33,519
3/4 Ton CrewCab 4X4 Pick-Up	2961	E-0	LTC4	2001	Chevrolet	K2500	8.1 liter - V8	N	1GCHK29G61E219381	908704	16,565
3/4 Ton CrewCab 4X4 Pick-Up	2962	E-20	LTC4	2001	Chevrolet	K2500	8.1 liter - V8	N	1GCHK23G61F116271	908694	26,110
15 Passanger Full Size Van	51292	E-0	PF15	2005	Chevrolet	Express 3500	6.0 liter - V8	NN	1GAHG39U951243239	921875	4,732
15 Passanger Full Size Van	51293	E-20	PF15	2005	Chevrolet	Express 3500	6.0 liter - V8	NN	1GAHG39UX51268828	921904	10,766
3/4 Ton SuperCab 4X4 Pick-Up	23572	E-0	LTS4	2002	Chevrolet	K2500	6.0 liter - V8	O	1GCHK24UX2E265312	911296	21,664
3/4 Ton SuperCab 4X4 Pick-Up	23573	E-20	LTS4	2002	Chevrolet	K2500	6.0 liter - V8	O	1GCHK24U22E264977	911297	19,736
Misc Truck	2771	E-20	MMIS	2000	Ford	F450	Triton V10 - 6.8L Gasoline SOHC/EFI 305-310 HP	P	1FDXF46SXYEE09307	906508	29,733
Misc Truck	2770	E-0	MMIS	2000	Ford	F450	Triton V10 - 6.8L Gasoline SOHC/EFI 305-310 HP	P	1FDXF46SXYEB80093	905351	20,131
8 Passanger Full Size Van	32225	E-20	PF8	2003	Ford	E150	Triton V8 - 4.6 L SOHC-EFI (W) 225-239HP	Q	1FMRE11L63HA25624	913343	6,063
8 Passanger Full Size Van	32224	E-0	PF8	2003	Ford	E150	Triton V8 - 4.6 L SOHC-EFI (W) 225-239HP	Q	1FMRE11L43HA19272	913334	17,712
Extenden Mini Passanger Van	42168	E-0	PME	2004	Dodge	Grand Caravan	2.4 liter - I4 - MPI	R	1D4GP24R04B546180	915298	13,503
Extenden Mini Passanger Van	42169	E-20	PME	2004	Dodge	Grand Caravan	2.4 liter - I4 - MPI	R	1D4GP24R24B543460	915292	7,626
Extenden Mini Passanger Van	51184	E-0	PME	2005	Dodge	Grand Caravan	3.8 LITER	S	2D4GP44L95R529436	920146	20,805
Extenden Mini Passanger Van	51185	E-20	PME	2005	Dodge	Grand Caravan	3.8 LITER	S	2D4GP44L05R529437	920147	21,299
Mini Utility 4 Door 4X4	2822	E-0	UM44	2001	Ford	Explorer	Essex 4 liter SOHC Gasoline 207-210	T	1FMZU72E51ZA40287	908451	21,259
Mini Utility 4 Door 4X4	2823	E-20	UM44	2001	Ford	Explorer	Essex 4 liter SOHC Gasoline 207-210	T	1FMZU72E71ZA40288	907420	20,920
Mini Utility 4 Door 4X4	51316	E-0	UM44	2005	Ford	Escape	HYBRID Triton 4.6L DOHC 300HP	U	1FMCU96H85KC96475	919869	21,815
Mini Utility 4 Door 4X4	51317	E-20	UM44	2005	Ford	Escape	HYBRID Triton 4.6L DOHC 300HP	U	1FMCU96HX5KC96476	919870	21,823
Mini Step Van	2766	E-20	UMSV	2000	WorkHorse	UCBC	4.3 L - V8 (code "W")	V	5B4GP32WXY3322531	906522	15,894
Mini Step Van	2765	E-0	UMSV	2000	WorkHorse	UCBC	4.3 L - V6 (code "W")	V	5B4GP32W1Y3322529	906512	17,190
Mini Step Van	2768	E-20	UMSV	2000	WorkHorse	UCBC	4.3 L - V6 (code "W")	W	5B4GP32W4Y3322539	906514	12,854
Mini Step Van	2767	E-0	UMSV	2000	WorkHorse	UCBC	4.3 L - V6 (code "W")	W	5B4GP32W7Y3322535	906513	11,471
Mini Step Van	2772	E-20	UMSV	2000	WorkHorse	UCBC	4.3 L - V6 (code "W")	X	5B4GP32W1Y3323180	906523	11,436
Mini Step Van	2769	E-0	UMSV	2000	WorkHorse	UCBC	4.3 L - V6 (code "W")	X	5B4GP32W3Y3323164	907326	10,107
Mini Cargo Van	2041	E-20	VMC	2000	Chevrolet	Astro	4.3 L - V6 (code "W")	Y	1GCDM19W9YB183594	905927	22,945
Mini Cargo Van	2040	E-0	VMC	2000	Chevrolet	Astro	4.3 L - V6 (code "W")	Y	1GCDM19W5YB187397	905926	22,013
Mini Cargo Van	2099	E-20	VMC	2000	Chevrolet	Astro	4.3 L - V6 (code "W")	Z	1GCDM19W0YB180681	905907	15,663
Mini Cargo Van	2096	E-0	VMC	2000	Chevrolet	Astro	4.3 L - V6 (code "W")	Z	1GCDM19W9YB156203	905354	18,379

TABLES AND FIGURES

Table 1 - Fuel Shipment Dates

E0	E20
6/22/2006	6/22/2006
7/6/2006	7/6/2006
7/19/2006	8/24/2006
8/10/2006	9/13/2006
8/24/2006	10/31/2006
9/8/2006	1/8/2007
9/28/2006	2/28/2007
10/27/2006	3/28/2007
11/6/2006	5/23/2007
11/22/2006	8/8/2007
12/5/2006	
1/4/2007	
1/31/2007	
2/21/2007	
2/28/2007	
3/13/2007	
3/23/2007	
4/23/2007	
5/2/2007	
5/21/2007	
6/11/2007	
6/22/2007	
7/20/2007	
8/7/2007	

Table 2 - Fuel Specifications

Month	Vapor Lock Protection	Distillation Class
Jan	5	E
Feb	5	E
Mar	5-4	E/D
April	4	D/A
May	4	A
June	3	A
July	3	A
Aug	3	A
Sep	3	A/C
Oct	3-4	C/D
Nov	4-5	D/E
Dec	5	E

Vapor Lock Protection	
	TVL=20 (F)
1	140
2	133
3	124
4	116
5	105
6	95

Volume Percent by ASTM D4815
Note: Summer Class A limits apply May 1 through September 15
RVPE is referenced in ASTM D4814
P absolute = P total - P gas

RVPE = 0.965(P total) - 0.0(P gas) - 0.055

Distillation Class	Vapor Pressure, max (psi)	Distillation Temperature, at % Evaporated, max 10%	50% min	50% max	90%	End Point, max	Distillation Residue, Volume %, max	Driveability Index
AA	7.8	158	170	250	374	437	2	1250
A	9.0	158	170	250	374	437	2	1250
B	10.0	149	170	245	374	437	2	1240
C	11.5	140	170	240	365	437	2	1230
D	13.5	131	150	235	365	437	2	1220
E	15.0	122	150	230	365	437	2	1200

Table 3a - Fuel Detail: Summer and Fall

Delivery date (E0) Sample #	Limits	6/22/2006 33755	7/6/2006 33756	7/19/2006 33758	8/10/2006 33759	8/24/2006 33760	9/8/2006 33762	9/28/2006 33764	10/27/2006 33765	11/6/2006 33766	11/22/2007 33768	12/5/2006 33769
Initial Boiling Point (F @min)	5-10 min	99.3 @6.2	104.9 @6.3	101.4 @5.9	100 @6.7	96.9 @7.6	99.5 @6.4	92.4 @3.2	99.6 @4.1	95.9 @3.9		96.4@7.8
5 ml Recovery (F @sec)	60-100 sec	121.8 @64	126.5 @71	111.9 @23	111.5 @27	124.5 @59	122.9 @59	116.6 @161	112.1 @101	105 @97		119.6@52
10ml	Class A, D, or E	126.1	131.1	125.2	123.6	134.9	130.1	121.1	113.9	106.5		128.3
T 50 min/max temp		170/250	170/250	170/250	170/250	170/250	170/250	170/240	150/235	150/235		
50ml	Class A, D, or E	206.2	210.3	207.3	205.3	215.9	206.7	208	200.4	203.7		213.9
90ml	Class A, D, or E	330.2	335.3	327.7	321	326.6	321.8	328	320.1	319.8		324.6
EP (mL @F)	Class A, D, or E	98.2 @421	98 @413.2	99.1 @411.4	99.1 @413.2	98.8 @413.6	98.5 @403	98.4 @413	98.3 @409.2	98.3 @406.4		8
Residual (mL)	Class A, D, or E	1.5	1.7	0.9	0.7	1	1.3	1	1.4	1.5		1.3
DI local max limit		1250	1250	1250	1250	1250	1250	1230	1220	1220		
DI	DI=1.5*T10+3*T50+T90	1137.95	1162.85	1137.4	112.3	1176.65	1137.05	1134.25	1092.15	1090.65		1158.75
Local max vapor press. limit		A / 9.0	A / 9.0	A / 9.0	A / 9.0	A / 9.0	A / 9.0	C / 11.5	D / 13.5	D / 13.5		
P total(PSI) @100F	Class A, D, or E	9.57	9.14	9.4	9.69	9.47	9.54	10.98	12.73	14.34		10.69
P gas(PSI) @100F	Class A, D, or E	0.74	0.68	0.64	0.68	0.68	0.73	67	0.75	0.8		0.74
P absolute(PSI) @100F	Class A, D, or E	8.83	8.46	8.76	9.01	8.79	8.81	10.31	11.98	13.55		9.95
RVPE(PSI) @100F	Class A, D, or E	9.18	8.77	9.02	9.3	9.08	9.15	10.54	12.23	13.78		10.26
Local TVL20 mim. temp °F		3 / 124°	3 / 124°	3 / 124°	3 / 124°	3 / 124°	3 / 124°	3 / 124°	4 / 116 °	4 / 116 °	5 / 105°	5 / 105°
TVL20 (F)		138.5	141.5	139.1	137.1	138.8	140.8	132.6	122.5	114.7		133.8
Ethanol (%)		0	0	0	0.17	0	0	0	0	0	14.87	0
MTBE (%)		0	0	0	0	0	0	0	0	0	0.86	0
Benzene (%)		1	2.17	1.23	0.89	2.12	2.1	0.94	0.97	0.98	14.01	0.68
Relative density	60F & 731mmHg	0.7212	0.7459	0.729	0.7343	0.7424	0.7423	0.7345	0.7162	0.7188	0.711	0.7206
API Gravity	60F & 731mmHg	64.71	58.19	62.61	61.2	59.09	59.13	61.15	66.08	65.37	67.31	64.85

Delivery date (E20) Sample #		6/22/2006 33754	7/6/2006 33757			8/24/2006 33761	9/13/2006 33763		10/31/2006 33767	
Initial Boiling Point (F @min)	5-10 min	97.7 @6.3	108.6 @5			92.8 @5.8	101.4 @6.3		107.6 @3.2	
5 ml Recovery (F @sec)	60-100 sec	118.2 @70				116.7 @69	117.3 @53		110.8 @87	
10ml	Class A, D, or E	120	121.4			119.4	120.7		113	
T 50 min/max temp		170/250	170/250	170/250	170/250	170/250	170/250	170/240	150/235	150/235
50ml	Class A, D, or E	155.1	155.3			153.3	154.7		154	
90ml	Class A, D, or E	310.1	312.4			310.4	315.3		307.6	
EP (mL @F)	Class A, D, or E	98.7 @392.7	99.2 @407.8			99 @399.9	98.7 @401.1		98.8 @394.3	
Residual (mL)	Class A, D, or E	1.2	0.7			0.6	1		0.6	
DI local max limit		1250	1250	1250	1250	1250	1250	1230	1220	1220
DI	DI=1.5*T10+3*T50+T90	955.4	960.4			949.4	960.45		939.1	
DI (Adjusted to E10)	DI=1.5*T10+3*T50+T90+2	1001.8	1008.7			1001.8	1007.1		994.0	
Local max vapor press. limit		A / 9.0	A / 9.0			A / 9.0	A / 9.0		D / 13.5	
P total(PSI) @100F	Class A, D, or E	10.69	10.24			10.65	10.69		13.07	
P gas(PSI) @100F	Class A, D, or E	0.55	0.38			0.74	0.48		0.57	
P absolute(PSI) @100F	Class A, D, or E	10.14	9.86			9.91	10.21		12.5	
RVPE(PSI) @100F	Class A, D, or E	10.26	9.83			10.22	10.26		12.56	
Local TVL20 mim. temp °F		3 / 124°	3 / 124°			3 / 124°	3 / 124°		4 / 116 °	
TVL20 (F)		124.4	127.1			124.2	124.1		117.2	
Ethanol (%)		19.29	20.1			21.8	19.4		22.84	
MTBE (%)		0	0			0	0		0	
Benzene (%)		0.91	0.85			1	1.1		1	
Relative density	60F & 731mmHg	0.7408	0.7397			0.7414	0.741		0.7329	
API Gravity	60F & 731mmHg	59.5	59.8			59.36	59.46		61.57	

Note: Samples out of specification by more than 1% are colored in cyan. Samples highlighted in red were contaminated.

Table 3b - Fuel Detail: Winter and Spring

Delivery date (E0) Sample #	Limits	1/4/2007 33770	1/31/2007 33772	2/21/2007 33773	2/28/2007 33774	3/12/2007 33776	3/23/2007 33777	4/23/2007 33779	5/2/2007 33780	5/21/2007 33781	6/11/2007 33783	6/22/2007 33784	7/20/2007 33785	8/7/2007 33786
Initial Boiling Point (F @min)	5-10 min	88.1@5.5	87.4@5.3	83.3@5.9	84.7@6.3	78.9@5.5	886.1@6.2	83.3@7	97.8@6.8	98.9@6.2	97.3@7.4	96.8@7	99.1@6.4	97.7@7.9
5 ml Recovery (F @sec)	60-100 sec	103.8@83	96.1@99	98.7@76	100.7@72	99.1@105	101.8@76	107.6@74	118.9@79	112.5@70	123.6@54	122.9@59	123.2@70	127.4@81
10ml	Class A, D, or E	109	100.8	103.1	105.2	103.2	106.1	114.8	126.1	126.3	134	132.9	128.8	135.5
T-50 min/max temp.		150/230	150/230	150/230	150/230	150/230	150/235	170/250	170/250	170/250	170/250	170/250	170/250	170/250
50ml	Class A, D, or E	203.3	198.7	194.7	193.1	192	196.1	204.6	212.1	209.3	212.1	211.6	209.6	220.2
90ml	Class A, D, or E	326.1	318	308.6	304.7	315.8	316.4	327.7	333.8	331.8	332.6	334	334.7	335.1
EP (mL @F)	Class A, D, or E	98.5@412.1	96.5@410.2	98.6@406.9	98.5@412.1	98.1@399.9	98.3@415.5	98.4@420.4	98.6@436	98.2@426.7	98.7@433	98.7@433	98.6@430.3	98.3@409.1
Residual (mL)	Class A, D, or E	1.2	1.2	1.2	1.2	1.5	1.5	1.5	0.9	1.5	1	1	1.2	1.5
Di local max limit		1200	1200	1200	1200	1200	1220	1250	1250	1250	1250	1250	1250	1250
DI	DI=1.5*T10+3*T50+T90	1099.5	1065.3	1047.35	1041.8	1046.6	1063.85	1113.7	1159	1149.15	1169.9	1168.15	1156.7	1198.95
Local max vapor press. limit		E/15.0	E/15.0	E/15.0	E/15.0	E/15.0	D/13.5	A/9.0	A/9.0	A/9.0	A/9.0	A/9.0	A/9.0	A/9.0
P total(PSI) @100F	Class A, D, or E	14.77	14.78	15.43	15.37	14.97	15.46	13.17	10.08	9.49	9.53	9.69	9.17	10.89
P gas(PSI) @100F	Class A, D, or E	0.84	0.93	0.97	0.86	0.8	0.91	0.8	0.8	0.77	0.75	0.75	0.84	0.49
P absolute(PSI) @100F	Class A, D, or E	13.92	13.85	14.46	14.52	14.17	14.55	12.37	9.28	8.72	8.77	8.93	8.33	10.4
RVPE(PSI) @100F	Class A, D, or E	14.2	14.21	14.83	14.78	14.39	14.36	13.85	9.87	9.1	9.14	9.3	8.79	10.85
Local TVL20 mim. temp. °F		5 / 105°	5 / 105°	5 / 105°	5 / 105°	5 / 105°	4 / 116°	4 / 116°	4 / 116°	4 / 116°	3 / 124°	3 / 124°	3 / 124°	3 / 124°
TVL20 (F)		111.7	109.8	107.4	106.2	109.1	106.4	118.7	138.5	140.3	140.8	140.7	140.4	140.5
Ethanol (%)		0	0	0	0	0	0	0	0	0	0	0	0	0
MTBE (%)		0	0	0	0	0	0	0	0	0	0	0	0	0
Benzene (%)		0.66	0.74	0.7	0.75	0.75	0.83	0.93	0.99	0.96	0.92	0.89	0.89	0.84
Relative density	60F & 731mmHg	0.7084	0.708	0.7075	0.7075	0.7068	0.7103	0.7195	0.7279	0.7267	0.7266	0.7232	0.7258	0.7333
API Gravity	60F & 731mmHg	68.23	68.35	68.51	68.51	68.49	67.52	65.95	62.89	63.21	63.24	64.17	63.45	61.47

Delivery date (E20) Sample #		1/8/2007 33771			2/28/2007 33775		3/28/2007 33778			5/23/2007 33782				8/8/2007 33787
Initial Boiling Point (F @min)	5-10 min	85.6@6.3			90.1@5.6		92.3@6.2			100.4@6.1				107.7@8
5 ml Recovery (F @sec)	60-100 sec	103.2@75			101.3@83		106@66			113.5@70				123.8@61
10ml	Class A, D, or E	105			104		110.8			116.4				127.9
T-50 min/max temp.		150/230	150/230	150/230	150/230	150/230	150/235	170/250	170/250	170/250	170/250	170/250	170/250	170/250
50ml	Class A, D, or E	156.2			154.9		158			156.2				159.4
90ml	Class A, D, or E	308.3			303.8		312.8			315.3				327.5
EP (mL @F)	Class A, D, or E	98.1@397.4			98.3@391.5		98.1@394.5			98.9@400.8				98@396.6
Residual (mL)	Class A, D, or E	1.7			1.4		1.5			0.9				1.5
Di local max limit		1200	1200	1200	1200	1200	1220	1250	1250	1250	1250	1250	1250	1250
DI	DI=1.5*T10+3*T50+T90	934.4			924.5		953			958.5				997.5
Di (Adjusted to E10)	DI=1.5*T10+3*T50+T90+2.4038*%vol Etoh	979.4			972.7		999.1			1003.4				1046.4
Local max vapor press. limit		E/15.0			E/15.0		D/13.5			A/9.0				A/9.0
P total(PSI) @100F	Class A, D, or E	15.21			15.21		11.4			11.82				9.62
P gas(PSI) @100F	Class A, D, or E	0.81			0.96		0.68			0.57				0.71
P absolute(PSI) @100F	Class A, D, or E	14.4			14.26		10.75			11.26				8.91
RVPE(PSI) @100F	Class A, D, or E	14.62			14.62		10.95			11.38				9.23
Local TVL20 mim. temp. °F		5 / 105°			5 / 105°		4 / 116°			4 / 116°				3 / 124°
TVL20 (F)		105			103.8		115.4			118.9				121.46
Ethanol (%)		18.74			20.05		19.18			18.66				20.33
MTBE (%)		0			0		0			0				0
Benzene (%)		0.85			0.79		0.91			0.84				0.88
Relative density	60F & 731mmHg	0.7245			0.729		0.7398			0.7398				0.7426
API Gravity	60F & 731mmHg	63.82			62.6		59.78			59.76				59.05

Note: Samples out of specification by more than 1% are colored in cyan.

Table 4a - FALL 2006 E0 AND E20 INSPECTIONS

INSPECTIONS	FALL E0	FALL E20	ASTM
Delivery Dates	9/08 and 9/28/07	9/13 and 10/31/07	—
Vol % Ethanol	0	21.1	—
T_{10}°F	126	117.0	131
T_{50}°F	207	154.0	150/235
T_{90}°F	325	317.0	365
DI①, max	1136	950.0	1220
TVL 20, min	137	121.0	116

① DIs of E20 samples were calculated according to the following equation:
$DI = (1.5)(T_{10}) + (3.0)(T_{50}) + (1.0)(T_{90}) + (2.404)(\text{Vol \% Etoh})$

Table 4b - WINTER 2006/2007 E0 AND E20 INSPECTIONS

INSPECTIONS	WINTER E0	WINTER E20	ASTM
Delivery Dates	1/04 and 2/21/07	1/08 and 2/28/07	—
Vol % Ethanol	0	19.4	—
T_{10}°F	106	105.0	122
T_{50}°F	199	156.0	150/230
T_{90}°F	318	306.0	365
DI①, max	1074	976.0	1200
TVL 20, min	10	105.0	105

① DIs of E20 samples were calculated according to the following equation:
DI = (1.5)(T10) + (3.0)(T50) + (1.0)(T90) + (2.404)(Vol % Etoh)

Table 4c - SPRING 2007 E0 AND E20 INSPECTION

INSPECTIONS	SPRING E0	SPRING E20	ASTM
Delivery Dates	3/23/07	3/28/07	—
Vol % Ethanol	0	19.2	—
T10 ° F	106	111.0	131
T50 ° F	196	158.0	150/235
T90 ° F	316	313.0	365
DI①, max	1064	999.0	1220
TVL 20, min	106②	115.0②	16

① DIs of E20 samples were calculated according to the following equation:
$DI = (1.5)(T10) + (3.0)(T50) + (1.0)(T90) + (2.404)(Vol\ \%\ Etoh)$

② The noted TVL 20's are not transposed nor are they typographical errors.°Refer to the discussion on page 11°beginning at paragraph three.

Table 4d - SUMMER 2006 E0 AND E20 INSPECTIONS

INSPECTIONS	SUMMER E0	SUMMER E20	ASTM
Delivery Dates	6/22 and 7/06/06	6/22 and 7/06/06	—
Vol % Ethanol	0	19.7	—
T10 ° F	129	121.0	158
T50 ° F	208	155.0	170/250
T90 ° F	333	311.0	374
DI①, max	1151	1006.0	1250
TVL 20, min	140	126	124

① DIs of E20 samples were calculated according to the following equation:
$DI = (1.5)(T10) + (3.0)(T50) + (1.0)(T90) + (2.404)(Vol\ \%\ Etoh)$

Table 5 - Vehicle Driveability Log Sheet

		Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Cold Start Temperature								
Odometer Reading								
Engine Block Heater used?(Oct-Apr)	Yes/No							
Cold Crank Start Time (sec)								
Cold Start	# attempts							
Cold Engine Idle Quality (Park/Neutral)	Smooth/Rough							
Cold Engine Idle Quality (Drive)	Smooth/Rough							
Cold Engine Drivewaway	Normal							
(Check One when applicable)	Stall [1] a							
	b							
	Hesitation [2]							
	Stumble [3]							
	Surge [4]							
	Backfire [5]							
Warm Engine Start Time (sec)								
Warm Start	# attempts							
Warm Engine Idle Quality (Park/Neutral)	Smooth/Rough							
Warm Engine Idle Quality (Drive)	Smooth/Rough							
Warm Engine Drivewaway	Normal							
(Check One when applicable)	Stall [1] a							
	b							
	Hesitation [2]							
	Stumble [3]							
	Surge [4]							
	Backfire [5]							
Road Condition	Wet							
(Check One)	Dry							
	Ice/Snow							
Fuel obtained away from Fleet HQ	Yes/No							
	Quantity							

Driver Comments:

1a-Stall while accelerating; 1b-Stall while decelerating
2 Temporary lack of vehicle response while accelerating
3 A short, sharp reduction in speed while accelerating
4 Repeated power fluctuations
5 A popping/backfire noise in the intake or exhaust systems

Table 6a - Vehicle Description and Lay Driver Reporting Frequency (Both Vehicles of Matched Pair Reporting)

Year	Make	Model	Engine	Pair	E0 License	E0 Summer % 17 wk	E0 Fall % 13 wk	E0 Winter % 14 wk	E0 Spring % 14 wk	E20 License	E20 Summer % 17 wk	E20 Fall % 13 wk	E20 Winter % 14 wk	E20 Spring % 14 wk
2005	Ford	Crown Victoria	Modular V8 - 4.6 L	E	51	0.00	0.00	15.31	0.00	52	0.00	24.18	20.41	0.00
2003	Ford	Focus	Zetec 2 liter DOHC	F	911099	0.00	40.66	58.16	52.94	911225	69.39	65.93	61.22	66.39
2003	Ford	Focus	Zetec 2 liter DOHC	G	914202	33.67	56.04	39.80	6.72	914204	0.00	39.56	55.10	32.77
2003	Ford	F450	Triton V10 - 6.8L Gas	H	914210	54.08	67.03	51.02	57.14	914209	68.37	65.93	53.06	64.71
2005	Ford	Ranger	Intec V8 - 5.4 L	I	919310	68.37	26.37	34.69	5.04	919309	30.61	47.25	7.14	0.00
2005	Ford	Ranger	Intec V8 - 5.4 L	J	918524	72.45	83.52	58.16	2.52	918518	62.24	42.86	51.02	42.02
2003	Dodge	Dakota	3.9 liter V6 MPI	K	914228	56.12	52.75	44.90	45.38	914226	47.96	59.34	55.10	54.62
2003	Ford	F250	Triton V8 - 5.4L	L	914206	45.92	47.25	35.71	24.37	913339	43.88	49.45	15.31	0.00
2006	Chevy	K2500	6.0 liter - V8	M	922080	21.43	15.38	0.00	0.00	922079	58.16	20.88	0.00	4.20
2001	Chevy	K2500	8.1 liter - V8	N	908704	18.37	52.75	4.08	0.00	908694	58.16	45.05	53.06	12.61
2002	Chevy	K2500	6.0 liter - V8	O	911296	57.14	39.56	52.04	51.26	911297	63.27	47.25	30.61	46.22
2000	Ford	F250	Triton V10 - 6.8L Gas	P	905351	48.98	53.85	58.16	43.70	906508	62.24	39.56	16.33	67.23
2000	UCBC	WorkHorse	4.3 L - V6 (code "W")	V	906512	4.08	58.24	62.24	0.00	906522	60.20	63.74	63.27	62.18
2000	UCBC	WorkHorse	4.3 L - V6 (code "W")	W	906513	47.96	0.00	0.00	0.00	906514	67.35	68.13	54.08	42.02
2000	UCBC	WorkHorse	4.3L - V6 (code "W")	X	907326	0.00	37.36	10.20	0.00	906523	64.29	50.55	52.04	63.87
2000	Chevy	Astro	4.3 L - V6 (code "W")	Z	905354	26.53	20.88	20.41	0.00	905907	55.10	60.44	46.94	0.00
2002	Dogde	Ram1500	4.3 L - V6 (code "X")	BB	911065	0.00	1.10	0.00	0.00	911233	13.27	10.99	0.00	0.00
2004	Chevy	Astro	4.3 L - V6 (code "X")	CC	916330	0.00	47.25	57.14	66.39	916332	0.00	46.15	59.18	59.66
2005	Chevy	Astro	4.3 L - V6 (code "X")	DD	918510	68.37	61.54	64.29	64.71	918512	59.18	42.86	61.22	66.39
2000	Ford	E350	Triton V8 - 4.6 L	EE	905945	29.59	0.00	0.00	0.00	905943	21.43	30.77	33.67	0.00
2001	Ford	E250	Triton V8 - 4.6 L	HH	908468	63.27	60.44	58.16	65.55	908685	59.18	63.74	56.12	58.82
2001	Ford	E250	Triton V8 - 5.4 L.	II	908684	64.29	63.74	56.12	64.71	908467	38.78	61.54	65.31	68.07
2002	Ford	E250	Triton V8 - 5.4 L.	KK	909216	37.76	0.00	0.00	0.00	909215	19.39	12.09	26.53	3.36

Table 6b - Vehicle Description and Lay Driver Frequency (Only E0 of the Pair Reporting)

Year	Make	Model	Engine	Pair	E0 License	% 17 wk	% 13 wk	% 14 wk	% 14 wk
2001	Ford	Focus	Zetec I4 - 2 liter	A	907376	31.63	0.00	0.00	0.00
2003	Ford	E150	Triton V8 - 4.6 L	Q	913334	55.10	47.25	33.67	0.00
2001	Ford	Explorer	Essex 4L SOHC Ga	T	908451	52.04	17.58	Sold	Sold
2000	Chevy	Astro	4.3 L - V6 (code "W")	Y	905926	56.12	32.97	0.00	0.00
2000	Chevy	Express	5.7 liter - V8	GG	911252	61.22	70.33	64.29	58.82
2001	Ford	E250	Triton V8 - 5.4 L.	JJ	907342	18.37	0.00	0.00	0.00

Table 6c - Vehicle Description and Lay Driver Frequency (Only E20 of the Pair Reporting)

Year	Make	Model	Engine	Pair	E20 License	Summer % 17 wk	Fall % 13 wk	Winter % 14 wk	Spring % 14 wk
2001	Ford	Focus	Zetec I4 - 2 liter	A	907395	66.33	31.87	Sold	Sold
2005	Chevy	Malibu	LV6 - I4 - 1.8 liter	C	920143	4.08	0.00	0.00	0.00
2005	Chevy	Impala	Essex 4L SOHC Gas	D	920121	1.02	0.00	0.00	0.00
2004	Dodge	Grand Caravan	2.4 liter - I4 - MPI	R	915292	45.92	46.15	0.00	0.00
2001	Ford	Explorer	Essex 4L SOHC Ga	T	907420	50.00	50.55	30.61	45.38
2001	Chevy	Express3500	6.0 liter - V8	FF	907401	58.16	63.74	55.10	62.18

Table 7 – Summary of Responses to Surveys

Fuel Type	Pair	License	Date	6/22/2006 - 9/30/2006 & 07/01/2007 Summer Events - Frequency	n1	10/1/2006 - 12/31/20006 Fall Events - Frequency	n2	01/01/2007 - 03/31/2007 Winter Events - Frequency	n3	04/01/2007 - 06/29/2007 Spring Events - Frequency	n4
E0	A	907376	7/3/2006 - 8/18/2006	Mediocre roughness on cold Idle on both P/N and D. Slightly longer (2 sec) cold crank time. Un-reported warm condition.	31						
E20	A	907395	6/26/2006 - 6/27/2006	Slightly longer (2 sec) cold and warm crank time	2						
E0	E	51	1/5/2007					2 attempts of crank with 2 sec crank time, slight roughness on idle on P/N and mediocre idle on D with cold engine	1		
E0	E	51	1/9/2007					2 sec cold cranktime and hesitation on cold driveaway.	1		
E0	E	51	1/11/2007					3 attempts of crank with 2 sec crank time, slight roughness on idle on P/N and harsh idle on D with cold engine. Surge in warm	1		
E0	E	51	2/22-23/2007					Mediocre roughness on warm idle P/N	2		
E20	E	52	11/7,11,12/2006			Slight rough on warn idle both P/N and D	3				
E20	E	52	11/25&26/2006			Slight rough on cold and warm idle both P/N and D	2				
E20	E	52	12/25/2006			Stall while accelerate on warm driveaway	1				
E20	E	52	2/10/2007					Slight rough on cold idle both P/N and D	1		
E0	F	911099	11/7/2006			Stumble on warm driveaway	1				
E0	F	911099	1/6-18/2007					2 sec cold crank time	7		
E0	F	911099	1/8/2007-3/30/2007					2 sec cold crank time	38		
E0	F	911099	1/16/2007-3/28/2007					2 sec warm crank time	28		
E0	F	911099	1/30/2007, 2/8/2007					3 sec cold crank time	2		
E0	F	911099	04/02/2007-4/11/2007							2 sec cold and warm crank time	6
E0	F	911099	4/20/2007							Mediocre roughness on warm idle on both P/N and D	1
E20	F	911225	7/17/2006	Stalled twice not long after cold start.	1						
E20	F	911225	12/4,5,7/2006			2 sec cold crank time	3				
E20	F	911225	1/16/2007 - 3/6/2007					2 sec cold crank time for 26% of the time. 3sec cold crank time for 23% of the time. 5 sec cold crank time for 3% of the time.	34		
E20	F	911225	4/5,6,9,11/2007							2 sec cold crank time and 1 of 2 cold crank attempt.	4
E20	F	911225	5/16/2007							5 sec cold crank time	1
E0	G	914202	11/10/2006			Hesitation on complete stop	1				
E0	G	914202	11/11/2006, 12/5/2006			2 sec cold crank time.	2				
E0	G	914202	2/13/2007					3 sec cold crank time, harsh cold idle on both P/n and D	1		
E20	G	914204	10/31/06 - 11/22/06			a little rough on P/N and D idle with either	21				
E20	G	914204	10/31/2006 - 11/2/2006			2 sec cold crank time	3				
E20	G	914204	11/31/2006-12/29/2006			Slight rough on cold and warm idle both P/N and D. 2 sec cold crank time 18% of the time	37				
E20	G	914204	1/3/2007-3/30/2007					Slight rough on cold and warm idle both P/N and D	57		
E20	G	914204	1/4/2007, 2/5,8,9/2007, 3/2/2007					2 sec cold crank time	5		
E20	G	914204	3/2/2007					Harsh cold idle on P/N	1		
E20	G	914204	3/8/2007					Mediocre roughness on warm idle D	1		
E20	G	914204	4/2/2007							2 sec cold and warm crank time	1
E20	G	914204	4/5/2007							2 sec cold crank time	1
E20	G	914204	5/11/2007							Mediocre roughness on cold idle on D.	1

Table 7 (Continued) – Summary of Responses to SurveysTable 7 (Continued) – Summary of Responses to Surveys

Fuel Type	Pair	License	Date	6/22/2006 - 9/30/2006 & 07/01/2007 Summer Events - Frequency	n1	10/1/2006 - 12/31/20006 Fall Events - Frequency	n2	01/01/2007 - 03/31/2007 Winter Events - Frequency	n3	04/01/2007 - 06/29/2007 Spring Events - Frequency	n4
E0	J	918524	6/30/2006	Surge on cold driveaway and hesitation on warm driveaway.	1						
E0	J	918524	7/4/2006	Surge on cold driveaway	1						
E0	J	918524	7/22/2006	Slight roughness on cold Idle on both P/N and D Stumble on cold driveaway.	1						
E0	J	918524	6/26/2006 - 7/7/2006	70% of the time were 2 sec cold crank	8						
E20	J	918518	6/26/2006 - 9/29/2006	About 5% of the time the vehicle took	9						
E20	J	918518	6/30/2006	Harsh idle on D	1						
E20	J	918518	7/10/2006	Slight roughness on warm Idle on both P/N and D	1						
E20	J	918518	8/29/2006	Slight roughness on warm Idle on P/N	1						
E20	J	918518	6/29,30/2006 & 7/13/2006	2 sec cold crank time	3						
E20	J	918518	7/10/2006	3 sec warm crank time	1						
E20	J	918518	10/18/2006			2 sec warm crank time	1				
E20	J	918518	12/6/2006			15 sec crank time with 5 attempt of cold crank	1				
E20	J	918518	12/13/2006			3 sec cold crank time with 2 cold crank attempt and mediocre P/N cold idle	1				
E20	J	918518	12/27,29/2006			2 sec cold crank time	2				
E20	J	918518	1/2/2007 - 3/30/2007					44% of the time has many multiple cold	33		
E20	J	918518	4/5,6,25/2007, 6/12/2007							2 sec cold crank time	4
E20	J	918518	4/19,25,27/2007,							2 sec warm crank time	13
E20	J	918518	4/18,20,26/2007,							3 sec warm crank time	7
E0	L	914206	7/11/2006 - 8/15/2006	2 sec cold and warm cranktime.	23						
E0	L	914206	8/16/2006 - 8/17/2006	2 sec warm cranktime.	2						
E0	L	914206	8/22/2006 - 8/23/2006	2 sec cold cranktime.	2						
E0	L	914206	11/13,17,29/2006 & 12/4,15/2006			2 warm crank attempt	5				
E0	L	914206	11/30/2006 & 12/13/2006			3 warm crank attempt	2				
E0	L	914206	2/6-15/2007, 3/13,15/2007					2-4 cold crank time	7		
E0	L	914206	1/9-17,23/2007, 2/15-22/2007					2-4 warm crank attempts	9		
E0	L	914206	1/10-19/2007					2-4 warm crank attempt	5		
E0	L	914206	6/4/2007							2 warm crank attempts.	1
E0	L	914206	6/11/2007							3 warm crank attempts.	1
E20	L	913339	6/30/2006 - 9/8/2006	Harsh idle and surge on both cold and warm to start with for 3 days then slight and mediocre idle in 50-50 distribution through out the dates.	32						
E20	L	913339	8/24/2006	Stumble on warm driveaway.	1						
E20	L	913339	6/30/2006 - 9/29/2006	20% and 10% of the time 2 sec cold and warm cranktime, respectively	21						
E20	L	913339	10/31/2006 - 11/1/2006, 12/5,7 18,27/2007			2 sec cold crank time	6				
E20	L	913339	2/5/2007-3/29/2007					69% and 20% of the time took 2 sec cold	16		

Table 7 (Continued) – Summary of Responses to Surveys

Fuel Type	Pair	License	Date	6/22/2006 - 9/30/2006 & 07/01/2007 Summer Events - Frequency	n1	10/1/2006 - 12/31/20006 Fall Events - Frequency	n2	01/01/2007 - 03/31/2007 Winter Events - Frequency	n3	04/01/2007 - 06/29/2007 Spring Events - Frequency	n4
E0	O	911296	8/28/2006 - 9/1/2006	3 warm attempts of cranking.	5						
E0	O	911296	6/29/2006 - 9/29/2006	99% and 98% of the time cold and warm crank time slightly longer (2 sec), respectively	58						
E0	O	911296	10/2/2006 - 11/22/2006			60% and 40% of the time cold and warm crank time slightly longer (2-3 sec), respectively.	13				
E0	O	911296	10/31/2006			2 cold attempts of cranking.	1				
E0	O	911296	11/6, 8, 10/2006			2 warm attempts of cranking.	3				
E0	O	911296	11/13/2006			Harsh idle on cold on D	1				
E0	O	911296	11/14/2006			Harsh idle on cold and warm both P/N and	1				
E0	O	911296	11/16/2006			2 cold and warm attempts of cranking.	1				
E0	O	911296	11/20/2006			2 cold attempts of cranking.	1				
E0	O	911296	11/27/2006 - 12/15/2006			2 sec cold and warm crank time	11				
E0	O	911296	11/27/2006 - 12/8/2006			Harsh idle on cold and warm both P/N and D	10				
E0	O	911296	1/1/2007 - 3/30/2007					90% and 40% of the time took 2 and 3 sec for cold crank time. 94% and 2% of the time took 2 and 3 warm crank time.	52		
E0	O	911296	1/16-19/2007					slight roughness on cold idle on both P/N and D	4		
E0	O	911296	4/2/2007- 7/27/2007							80% and 92% of the time took 2 sec for cold and warm crank time, respectively.	26
E0	O	911296	7/2/2007/2007- 7/27/2007	47% and 32% of the time took 2 sec for cold and warm crank time, respectively.	19						
E0	O	911296	5/22,23/2007							Rough idle during both cold and warm on both P/N and D.	2
E20	O	911297	6/30/2006 - 7/6/2006	Cranking time were slightly longer (2-3 sec)	5						
E20	O	911297	7/17/2006 - 8/3/2006	Slight roughness on warm and cold Idle on	15						
E20	O	911297	10/11/2006 - 10/13/2006			Hesitation on cold driveaway and longer	3				
E20	O	911297	10/30/2006			Harsh idle on cold and warm both P/N and D. longer cranking time on both warm and cold.	1				
E20	O	911297	11/6/2006			Mediocre idle on cold on P/N, hesitation on cold driveaway. Harsh idle on warm both P/N and D. Longer cranktime on cold and warm.	1				
E20	O	911297	11/10/2006 - 11/16/2006			Mediocre idle on warm on both P/N and D.	5				
E20	O	911297	10/2 11 12 13 30/2006 &			Longer cold crank time (3-5sec)	9				
E20	O	911297	10/6 11 12 30/2006 & 11/8,9,10,15,16/2006			Longer warm crank time (3-5sec)	9				
E20	O	911297	11/20/2006 - 12/29/2006			2-6 sec cold and warm crank time with 12% of 2 attempts cold crank and 83% multiple warm crank from 2-5 attempts	25				
E20	O	911297	11/27/2006 - 12/1/2006			Check engine light on - fuel regulator replaced	5				
E20	O	911297	1/3-4/2007					4 sec cold crank time and harsh cold idle on both P/N and D.	2		
E20	O	911297	2/6,8,9/2007, 3/13,26-30/2007					2 Sec cold crank time	9		
E20	O	911297	3/13,26,27/2007					2 sec warm crank time	3		
E20	O	911297	4/9,30/2007, 5/16,23/2007, 6/4/2007							2 Sec cold crank time	5
E20	O	911297	4/20,30/2007							2 sec warm crank time	2
E20	O	911207	5/15,16,22,23/2007							Slight roughness on cold idle on P/N	4
E20	O	911297	5/15,18/2007							D.	3

Table 7 (Continued) – Summary of Responses to Surveys

Fuel Type	Pair	License	Date	6/22/2006 - 9/30/2006 & 07/01/2007 Summer Events - Frequency	n1	10/1/2006 - 12/31/20006 Fall Events - Frequency	n2	01/01/2007 - 03/31/2007 Winter Events - Frequency	n3	04/01/2007 - 06/29/2007 Spring Events - Frequency	n4
E0	P	905351	11/30/2006, 12/1,7/2006			2 sec cold crank time	3				
E20	P	906508	6/29/2006 - 9/29/2006	Occasional longer cranktime with 1 time 8	13						
E20	P	906508	7/3/2006 & 9/12/2006	Slight roughness on warm idle on P/N	2						
E20	P	906508	10/23/2006 & 11/9/2006			2 and 3 sec cold and warm cranktime, respectively.	2				
E20	P	906508	1/2/2007					3 sec cold crank time and 3 sec warm	1		
E20	P	906508	7/23-24/2007	5 sec cold cranktime.	2						
E0	V	906512	9/20/2006 - 9/22/2006	Mediocre idle on warm and cold on both	3						
E0	V	906512	1/22/2007-3/30/2007					P/N and D	50		
E20	V	906522	11/21/2006			2 sec warm crank time	1				
E20	V	906522	1/29/2009, 2/5-8/2007					2-3 sec cold crank time	5		
E0	CC	916330	10/26/2006			2 attempts of crank with 2 sec crank time and mediocre idle on both P/N and D with cold engine	1				
E0	CC	916330	3/12-30/2007					1 sec cold and warm crank time. Slight roughness on idle both on P/N and D on both cold and warm condition.	12		
E0	CC	916330	4/1-6/29/2007							Slight roughness on idle both on P/N and D on both cold and warm condition.	67
E0	CC	916330	7/2-19/2007	Slight roughness on idle both on P/N and D on both cold and warm condition.	13						
E20	CC	916332	1/3/2007					Stall while decelerating with cold engine	1		
E20	CC	916332	1/16/2007-1/19/2007					Stall while decelerating with cold and engine	4		
E0	DD	918510	6/29/2006 - 6/30/2006	2 sec cold cranktime	2						
E20	DD	918512	6/27/2006 - 6/29/2006	Slight roughness on cold idle on both P/N and D	3						
E20	DD	918512	7/5 & 6/2006	Slight roughness on warm idle on both P/N and D	2						
E20	DD	918512	7/11/2006 - 7/13/2006	Slight roughness on cold idle on both P/N and D	3						
E0	HH	908468	6/27/2006 - 9/29/2006	80% of the time cold crank time slightly longer (2 sec). Un-reported warm crank time	50						
E0	HH	908468	10/9/2006 - 12/22/2006			2 sec cold crank time 91% of the time	51				
E0	HH	908468	1/3/2007 - 2/2/2007					2 sec cold crank time	26		
E0	HH	908468	2/5-9/2007					3 sec cold crank time	5		
E0	HH	908468	2/12/2007-3/30/2007					2 sec cold crank time	28		
E0	HH	908468	4/2/2007-7/29/2007							2 sec cold crank time	61
E0	HH	908468	4/2/2007-7/29/2007	2 sec cold crank time	16						
E20	HH	908685	6/27/2006 - 9/22/2006	3 sec cold crank time with occasionally 2 sec crank time and 2 sec warm crank time with occasionally 3 sec.	58						
E20	HH	908685	10/3/2006-11/14/2006 & 12/01/2006-12/29/2006			3 sec cold crank time	52				
E20	HH	908685	11/15-30/2006			2 sec cold crank time	10				
E20	HH	908685	1/2/2007 - 2/2/2007					3 sec cold and warm crank time	24		
E20	HH	908685	2/5-9/2006					4 sec cold crank time and 4 sec warm	4		
E20	HH	908685	2/12/2007-2/28/2007					3 sec cold and warm crank time	12		
E20	HH	908685	3/8/2007-3/30/2007					2 sec cold and warm crank time	16		
E20	HH	908685	4/3/2007-5/4/2007							2 sec cold and warm crank time	69
E0	KK	909216	6/28/2006 - 8/18/2006	Slightly longer cold and warm (2 sec) crank	37						
E20	KK	909215	6/29/2006 & 8/31/2006	Slightly longer cold crank time.	2						
E20	KK	909215	7/21/2006	Slightly longer warm crank time.	1						
E20	KK	909215	11/6,20,27/2006			2 sec cold crank time	3				
E20	KK	909215	12/11/2006			3 sec cold crank time with 2 cold crank	1				
E20	KK	909215	12/12/2006			3 sec cold crank time	1				
E20	KK	909215	12/18/2006			Mediocre harshness on cold on both P/N and D	1				
E20	KK	909215	1/10/2007					2 sec cold crank time	1		
E20	KK	909215	1/29/2007, 2/1/2007					2 sec warm crank time	2		
E20	KK	909215	1/18/2007					Harsh cold idle on both P/N and D	1		
E20	KK	909215	2/26/2007					2 attempts of cold crank	1		
E20	KK	909215	7/20/2007	Mediocre roughness warm idle on both P/N and D	1						

Table 7 (Continued) – Summary of Responses to Surveys

Fuel Type	Pair	License	Date	6/22/2006 - 9/30/2006 & 07/01/2007 Summer Events - Frequency	n1	10/1/2006 - 12/31/20006 Fall Events - Frequency	n2	01/01/2007 - 03/31/2007 Winter Events - Frequency	n3	04/01/2007 - 06/29/2007 Spring Events - Frequency	n4
E0	N	908704	8/23/2006 - 9/21/2006	Mediocre roughness on cold and warm idle on both P/N and D	12						
E0	N	908704	8/21/2006 - 8/22/2006	2 sec cold and warm cranktime.	2						
E0	N	908704	10/3/2006, 11/29/2006, 12/18, 27,28/2006			Mediocre harshness of cold and warm idle on both P/N and D	5				
E0	N	908704	10/9-12,16,19,20,28/2006, 11/27,29/2006, 12/11,17,18,28,29/2006			2 sec cold crank time	14				
E0	N	908704	10/9-20,28/2006, 11/27,29/2006, 12/17,18/2006			2 sec warm crank time	13				
E0	N	908704	1/2-5/2007					Slight rough on cold idle both P/N and D	4		
E0	N	908704	1/4-5/2007					2 sec cold crank time	2		
E0	Q	913334	11/29/2006			3 sec warm crank time	1				
E0	Q	913334	12/1/2006			2 sec warm crank time	1				
E0	Q	913334	1/26/2007					Mediocre roughness on cold idle	1		
E0	Q	913334	1/29/2007 - 2/16/2007					2-4 sec cold crank time	15		
E0	T	908451	7/6/2006 - 9/29/2006	20% and 16% of the time cold and warm crank time were slightly longer (2-3 sec)	15						
E0	W	906513	7/18/2006 - 9/1/2006	Multiple attempts of warm crank, anywhere from 2-8 tries	35						
E0	W	906513	7/28/2006 - 8/18/2006	Multiple attempts of warm crank, 2 tries	5						
E0	Y	905926	7/5/2006	Slightly longer cold cranktime.	1						
E0	Y	905926	10/2,3,4,16,17,23/2006			Slightly longer cold cranktime. Ranging from 2-4 sec	6				
E0	Z	905354	6/28/2006 - 9/29/2006	2 sec cold crank time throughout the	28						
E0	Z	905354	10/2/2006 - 10/26/2006			2 sec cold crank time throughout the	21				
E0	Z	905354	10/2/2006			Stumble on cold driveaway	1				
E0	JJ	907342	8/4/2006	Hesitation on warm driveaway.	1						
E0	JJ	907342	8/29/2006 - 8/6/2006	Occasional longer cold and warm crank time	5						

Table 7 (Continued) – Summary of Responses to Surveys

Fuel Type	Pair	License	Date	6/22/2006 - 9/30/2006 & 07/01/2007 Summer Events - Frequency	n1	10/1/2006 - 12/31/20006 Fall Events - Frequency	n2	01/01/2007 - 03/31/2007 Winter Events - Frequency	n3	04/01/2007 - 06/29/2007 Spring Events - Frequency	n4
E20	M	922079	8/28/2006 - 9/5/2006	Hesitation on warm driveaway.	6						
E20	M	922079	7/20/2007	Mediocre roughness warm idle on P/N.	1						
E20	R	915292	7/27/2006 - 9/29/2006	2 sec cold cranktime. With 26 reported.	26						
E20	R	915292	8/15/2006 - 9/1/2006	2 sec warm crank time With 9 reported	8						
E20	R	915292	10/2/2006 - 11/3/2006			2 sec cold crank time	22				
E20	R	915292	10/30/2006 - 11/3/2006			2 cold attempts of cranking. With 16 reported.	5				
E20	R	915292	12/11-13/2006			mediocre roughness on cold idle P/N	3				
E20	X	906523	5/9/2007 - 6/19/2007							2 sec cold and warm crank time	17
E20	BB	911233	6/26/2006 - 7/27/2006	Slightly longer cold and warm crank time.	12						
E20	EE	905943	6/26/2006 - 8/4/2006	Cold idle on both P/N and D has start out with mediocre roughness and one day of harsh roughness in between for 5 days. Afterwards, it became slight roughness for 6 days. Then, and alternating between good idle and slight harness up to the date specified.	18						
E20	EE	905943	6/26/2006 - 8/4/2006	Similarly, on the warm idle both P/N and D It started out from mediocre roughness with occasionally harsh idle and becomes better and maintain at slight roughness to the date specified.	21						
E20	EE	905943	7/10 & 17-21/2006	2 attempts of cold crank	6						
E20	EE	905943	7/6 , 7, 19/2006	2 attempts of warm crank	3						
E20	EE	905943	6/26/2006 - 8/4/2006	2 sec cold and warm cranktime. With 2 of 3 sec cold crank at the end of June	25						
E20	EE	905943	11/20/2006-12/29/2006			2 sec cold crank time	27				
E20	EE	905943	1/2/2007-3/2/2007					2 sec cold crank time	33		
E20	EE	905943	2/6/2007 - 3/2/2007					2 sec warm crank time	19		
E20	FF	907401	4/30/2007							2 sec cold crank time	1
E20	II	908467	6/26/2006 - 9/28/2006	90% of the time were 2 sec cold and warm crank time	42						
E20	II	908467	10/2/2006 - 12/29/2006			2 sec cold and warm crank time	56				
E20	II	908467	1/2/2007 - 3/30/2007					2 sec cold and warm crank time	63		
E20	II	908467	4/2/2007 - 7/29/2007							2 sec cold and warm crank time	55
E20	II	908467	4/2/2007 - 7/29/2007	2 sec cold and warm crank time	25						

Table 8 – Summary of Lay Drivers' Reports and Driveability Events

Events reported	Fuel Type			
	E0		E20	
Total weekly report forms submitted				
Summer	490		424	
Fall	242		386	
Winter	383		357	
Spring	220		188	
Overall	1335		1355	
Number of vehicles reporting events (%)				
Summer	17	43%	15	38%
Fall	12	30%	14	35%
Winter	23	58%	14	35%
Spring	7	18%	8	20%
Average Quaterly Rep. Events	**15**	**37%**	**13**	**32%**
Summary of response rates				
	% response.			
	E0		E20	
Through Summer	31.6%		36.0%	
Through Fall	35.0%		40.8%	
Through Winter	33.7%		39.1%	
Through Spring	31.8%		39.2%	
Overall summary of response rates				
Number of sheets completed	724		893	
Possible Sheets (57 wks *40)	2280		2280	
% response.	31.75%		39.17%	

Table 9 – Lay Driver Demerit Score Conversion

	Crank Time	# Attempt	P/N & D	Drivaway
Blank	2	4	2	3
Good	----	----	0	0
1	0	0	2	----
2	1	8	4	----
3	2	16	8	----
4	4	24	----	----
5	8	32	----	----
6	----	40	----	----
7	----	48	----	----
8	----	56	----	----
Hesitation	----	----	----	2
Stumble	----	----	----	4
Surge	----	----	----	8
Stall-A	----	----	12	12
Stall-B	----	----	----	16
Backfire	----	----	----	24

Table 10a – Average and 95% Confidence Intervals of Lay Driver

Demerit Scores: ***Results are weighted by total number of reports.*** Results shown only for paired vehicles, both reporting. Shaded results are statistically different at a 95% confidence level.

Fuel	E0		E20	
Season	Ave. demerits	95% CI	Ave. demerits	95% CI
Summer	5.84	0.51	5.89	0.46
Fall	5.29	0.59	6.49	0.58
Winter	4.59	0.49	5.13	0.58
Spring	2.95	0.41	4.97	0.56

Table 10b – Average and 95% Confidence Intervals of Lay Driver

Demerit Scores: ***Results are weighted by averages for individual vehicles.*** Results shown only for paired vehicles, both reporting. None of the differences between E0 and E20 are statistically significant.

Fuel	E0		E20	
Season	Ave. demerits	95% CI	Ave. demerits	95% CI
Summer	7.09	3.36	7.15	3.23
Fall	5.94	3.72	5.40	3.30
Winter	5.70	3.35	5.48	2.80
Spring	3.28	2.84	5.76	3.42

Table 11 – Average Lay Driver Demerit Scores Grouped by Vehicle and Season

Count denotes number of reports received. Results are only shown for paired vehicles in each season.

Pair	Fuel	Summer		Fall		Winter		Spring	
		Score	Count	Score	Count	Score	Count	Score	Count
2	E0			26.0	1				
2	E20			0.0	10				
3	E0	8.0	13	0.7	43	2.3	56	9.0	64
3	E20	8.0	18	14.0	42	15.4	58	14.4	53
4	E0	2.1	88	0.0	56	0.0	62	0.0	56
4	E20	1.0	73	0.0	39	0.0	60	0.0	63
5	E0	13.4	29						
5	E20	15.6	21						
8	E0	8.3	78	6.9	55	6.9	56	8.0	62
8	E20	6.5	77	6.6	58	4.3	55	6.5	51
9	E0	0.0	81	0.0	58	0.0	55	0.0	59
9	E20	5.9	63	2.0	56	2.0	63	3.4	56
11	E0	2.0	37						
11	E20	4.4	23						
A	E0	23.7	31						
A	E20	1.4	65						
E	E0	15.0	4			11.1	15		
E	E20	26.0	5			5.6	20		
F	E0	0.0	14	1.0	35	1.4	57	1.0	49
F	E20	0.4	87	0.3	60	1.0	60	0.3	60
G	E0			7.3	52	11.1	39	11.4	8
G	E20			9.4	36	8.2	55	10.2	39
H	E0	1.9	72	0.6	61	1.6	49	2.0	49
H	E20	0.0	81	0.0	60	0.0	52	0.3	63
I	E0	4.8	51	4.0	40	3.1	34		
I	E20	8.1	30	6.8	43	5.4	7		
J	E0	3.5	71	1.4	78	5.7	59	0.0	3
J	E20	6.1	67	6.6	39	18.5	50	4.7	44
K	E0	1.2	60	0.3	38	0.0	44	0.4	49
K	E20	11.6	61	7.6	54	10.1	55	13.5	51
L	E0	8.9	50	5.9	43	11.4	35		
L	E20	11.1	43	1.0	46	7.0	15		
M	E0	26.0	57	26.0	15				
M	E20	22.6	62	26.0	19				
N	E0	11.2	18	13.1	48	20.5	4		
N	E20	4.1	57	0.0	41	0.0	52		
O	E0	4.8	75	11.7	36	3.9	51	4.3	42
O	E20	7.2	81	18.2	43	6.6	30	6.4	37
P	E0	0.0	52	0.1	49	0.0	57	0.0	48
P	E20	3.8	80	5.5	36	7.8	16	3.6	61
T	E0	6.1	51	5.7	16				
T	E20	6.3	64	0.0	46				
V	E0			0.0	53	17.8	59		
V	E20			2.8	58	1.4	62		
Y	E0	0.5	55	0.8	32	0.0	20		
Y	E20	0.0	1	1.2	46	0.0	51		
Z	E0	7.5	26	7.2	19				
Z	E20	0.0	53	0.0	55				

Table 12 - Trained Raters' Scores

				Fall			Winter			Spring			Summer	
Car	License	Pair	Fuel	Run #	twd	log twd+1	Run #	twd	log twd+1	Run #	twd	log twd+1	twd	log twd+1
42405	916330	CC	E-0	9	6	1.9459	10	10.5	2.4423	9	17	2.8904	13	2.6391
42406	916332	CC	E-20	8	9	2.3026	10	19.5	3.0204	6	32	3.4965	30	3.4340
2464	905945	EE	E-0	5	6	1.9459	4	21.5	3.1135	7	36	3.6109	36.5	3.6243
2465	905943	EE	E-20	9	7	2.0794	7	23.5	3.1987	5	18.5	2.9704	24	3.2189
22471	909216	KK	E-0	4	7.5	2.1401	5	27	3.3322	9	22	3.1355	26	3.2958
22472	909215	KK	E-20	7	9	2.3026	2	29.5	3.4177	4	11	2.4849	22	3.1355

				Fall			Winter			Spring			Summer	
Car	License	Pair	Fuel	Run #	twd	log twd+1	Run #	twd	log twd+1	Run #	twd	log twd+1	twd	log twd+1
51058	920142	C	E-0	5	12.5	2.6027	3	25	3.2581	6	20.5	3.0681	15	2.7726
51059	920143	C	E-20	3	10.5	2.4423	1	25.5	3.2771	1	9	2.3026		
51085	920145	D	E-0	2	3	1.3863	6	39	3.6889	7	4.5	1.7047	12	2.5649
51086	920121	D	E-20	3	17.5	2.9178	4	24.5	3.2387	4	5	1.7918		
22020	911099	F	E-0	1	11	2.4849	9	35.5	3.5973				16	2.8332
22021	911225	F	E-20				1	36	3.6109				22	3.1355
32224	913334	Q	E-0	10	5.5	1.8718	6	21.5	3.1135				4	1.6094
32225	913343	Q	E20							2	6.5	2.0149	15.5	2.8034
51184	920146	S	E-0	1	11	2.4849	5	25	3.2581	10	14	2.7081	16	2.8332
51185	920147	S	E-20				7	10	2.3979	3	13	2.6391	18	2.9444
2765	906512	V	E-0	10	26	3.2958	11	17.5	2.9178	2	27.5	3.3499		
2766	906522	V	E-20	6	12	2.5649	8	41	3.7377	8	11	2.4849	16	2.8332
22403	911065	BB	E-0	7	15	2.7726	9	17	2.8904	8	19	2.9957	25	3.2581
22404	911233	BB	E-20	6	18.5	2.9704	8	20.5	3.0681				11	2.4849
2822	908451	T	E-0	8	19.5	3.0204		Sold			Sold		Sold	
2820		T	E0	2820 replaced 2822			12	6.5	2.0149	1	22.5	3.1570	9.5	2.3514
2823	907420	T	E-20	4	14.5	2.7408	2	12	2.5649	5	20	3.0445	30.5	3.4500
41288	916370	MM	E-0	11	3.5	1.5041		Sold			Sold		Sold	
41289	917503	MM	E-20	2	10.5	2.4423		Sold			Sold		Sold	
51292	921875	NN	E-0	NN replaced MM			3	22	3.1355	3	16	2.8332	16.5	2.8622
51293	921904	NN	E-20	NN replaced MM			11	48.5	3.9020				7.5	2.1401

Paired vehicles only				
log twd+1	E-0	E-20		
Average			T	Treject
Fall	2.29	2.53	-0.98	2.20
Winter	3.06	3.22	-0.81	2.09
Spring	2.95	2.65	1.10	2.16
Summer	2.81	2.97	-0.65	2.14
95% Confidence Interval				
Fall	0.51	0.23		
Winter	0.33	0.31		
Spring	0.48	0.43		
Summer	0.45	0.33		

All vehicles including unpaired				
log twd+1	E-0	E-20		
Average			T	Treject
Fall	2.29	2.53	-1.22	2.11
Winter	3.06	3.22	-0.82	2.09
Spring	2.95	2.58	1.53	2.12
Summer	2.79	2.96	-0.83	2.10
95% Confidence Interval				
Fall	0.37	0.23		
Winter	0.29	0.31		
Spring	0.36	0.41		
Summer	0.36	0.30		

Table13– Random Samples Taken from Vehicle Fuel Tanks During Spring Trained Raters Evaluation on April 19, 2007

Vehicle #	Lab ID	Volume % ETOH
2823	33796	20.17
2820	33797	0.00
42405	33798	18.74
42406	33799	0.00
2464	33800	19.75
2465	33801	0.00
2765	33802	19.70
2766	33803	0.00

Table 14– Random Samples Taken from Vehicle Fuel Tanks During Summer Trained Raters Evaluation on July 29, 2007

Vehicle #	Lab ID	Volume % ETOH
32225	33826	8.06
209	33827	0
32224	33828	0
22472	33829	18.24
2460	33830	0
2465	33831	18.62

Possible contaminated sample for Vehicle 32225

Table 15 – Summary of Fuel Economy Measurements: Differences refer to percentage change in fuel economy with E0 the base case. Outliers are highlighted in yellow.

	E0			E20			
Pair	VID	YEAR MAKE MODEL	MPG	VID	YEAR MAKE MODEL	MPG	%Ch
A	002302	2001 FORD FOCUS	18.9	2320	2001 FORD FOCUS	SOLD	--
AA	021401	2002 DODGE RAM 1500	10.2	021402	2002 DODGE RAM 1500	8.5	-16%
B	051046	2005 TOYOTA PRIUS hybrid	40.7	051047	2005 TOYOTA PRIUS hybrid	38.5	-6%
BB	022403	2002 DODGE RAM 1500	10.0	022404	2002 DODGE RAM 1500	7.2	-28%
C	051058	2005 CHEVROLET MALIBU	25.9	051059	2005 CHEVROLET MALIBU	26.3	2%
CC	042405	2004 CHEVROLET ASTRO	12.3	042406	2004 CHEVROLET ASTRO	11.9	-4%
D	051085	2005 CHEVROLET IMPALA	22.6	051086	2005 CHEVROLET IMPALA	22.8	1%
DD	052402	2005 CHEVROLET ASTRO	9.7	052403	2005 CHEVROLET ASTRO	11.2	15%
E	053096	2005 FORD CROWN VICTORIA	6.9	053097	2005 FORD CROWN VICTORIA	7.1	4%
EE	002464	2000 FORD E350	6.6	002465	2000 FORD E350	6.3	-5%
F	022020	2003 FORD FOCUS	14.7	022021	2003 FORD FOCUS	18.2	24%
FF	002477	2001 CHEVROLET EXPRESS 3500	9.3	002478	2001 CHEVROLET EXPRESS 3500	7.6	-18%
G	032033	2003 FORD FOCUS	17.6	032034	2003 FORD FOCUS	18.6	6%
GG	002535	2000 CHEVROLET EXPRESS 2500	7.2	002539	2000 CHEVROLET EXPRESS 2500	8.5	19%
H	032644	2003 FORD F350	6.7	032674	2003 FORD F450	4.2	-37%
HH	002479	2001 FORD E250	7.6	002480	2001 FORD E250	7.2	-6%
I	073500	2005 FORD RANGER	14.7	073501	2005 FORD RANGER	12.7	-13%
II	002481	2001 FORD E250	6.0	002482	2001 FORD E250	6.6	11%
J	073502	2005 FORD RANGER	17.1	073503	2005 FORD RANGER	13.8	-19%
JJ	002470	2001 FORD E250	7.5	002501	2001 FORD E250	8.2	11%
K	033542	2003 DODGE DAKOTA	8.4	033543	2003 DODGE DAKOTA	7.8	-6%
KK	022471	2002 FORD E250	9.2	022472	2002 FORD E250	13.5	47%
L	032574	2003 FORD F250	8.3	032575	2003 FORD F250	8.2	-1%
LL	061265	2006 CHEVROLET EXPRESS 3500	13.3	061266	2006 CHEVROLET EXPRESS 3500	13.5	2%
M	062570	2006 CHEVROLET K2500	7.4	062571	2006 CHEVROLET K2500	6.4	-13%
N	002961	2001 CHEVROLET K2500	4.1	002962	2001 CHEVROLET K2500	6.8	66%
NN	051292	2005 CHEVROLET EXPRESS 3500	11.7	051293	2005 CHEVROLET EXPRESS 3500	11.1	-6%
O	23572	2002 CHEVROLET K2500	--	023573	2002 CHEVROLET K2500	7.5	--
P	002770	2000 FORD F450	4.1	002771	2000 FORD F450	5.2	28%
Q	032224	2003 FORD E150	9.1	032225	2003 FORD E150	9.3	2%
R	042168	2004 DODGE GRAND CARAVAN	13.1	042169	2004 DODGE GRAND CARAVAN	12.7	-3%
S	051184	2005 DODGE GRAND CARAVAN	17.2	051185	2005 DODGE GRAND CARAVAN	15.2	-11%
T	002820	2001 FORD EXPLORER	14.9	002823	2001 FORD EXPLORER	11.7	-21%
U	051316	2005 FORD ESCAPE hybrid	23.7	051317	2005 FORD ESCAPE hybrid	24.4	3%
V	002765	2000 WORKHORSE UCBC	6.4	002766	2000 WORKHORSE UCBC	7.8	22%
W	002767	2000 WORKHORSE UCBC	7.1	002768	2000 WORKHORSE UCBC	5.8	-18%
X	002769	2000 WORKHORSE UCBC	6.6	002772	2000 WORKHORSE UCBC	7.2	10%
Y	002040	2000 CHEVROLET ASTRO	11.2	002041	2000 CHEVROLET ASTRO	13.3	19%
Z	002096	2000 CHEVROLET ASTRO	9.4	002099	2000 CHEVROLET ASTRO	9.9	6%

	E0		E20	
min	4.1	min	4.2	
max	40.7	max	38.5	
Paired Average	11.9	Paired Average	11.8	-0.6%
		Average difference between pairs		1.7%
		Standard deviation		19.9%
		95% confidence interval		6.6%
		Average difference outliers removed		-1.4%

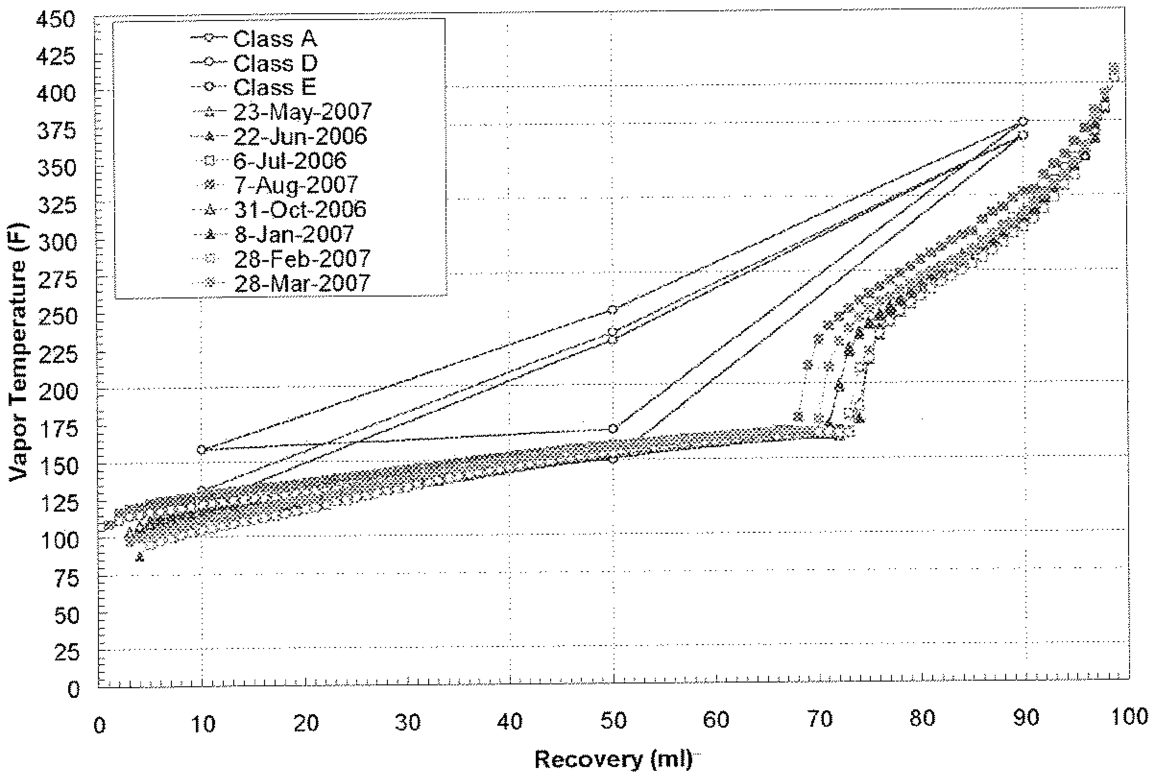

Figure 1a – Distillation Data for E20 Fuels. Summer fuels are plotted in warm colors, winter fuels in cool colors. Also shown are ASTM limits for fuels Class A (summer, May 1 – September 15), Class D (fall, spring, September 16 – November 15, March 16 - April 30), and Class E (winter, November 15 – March 15).

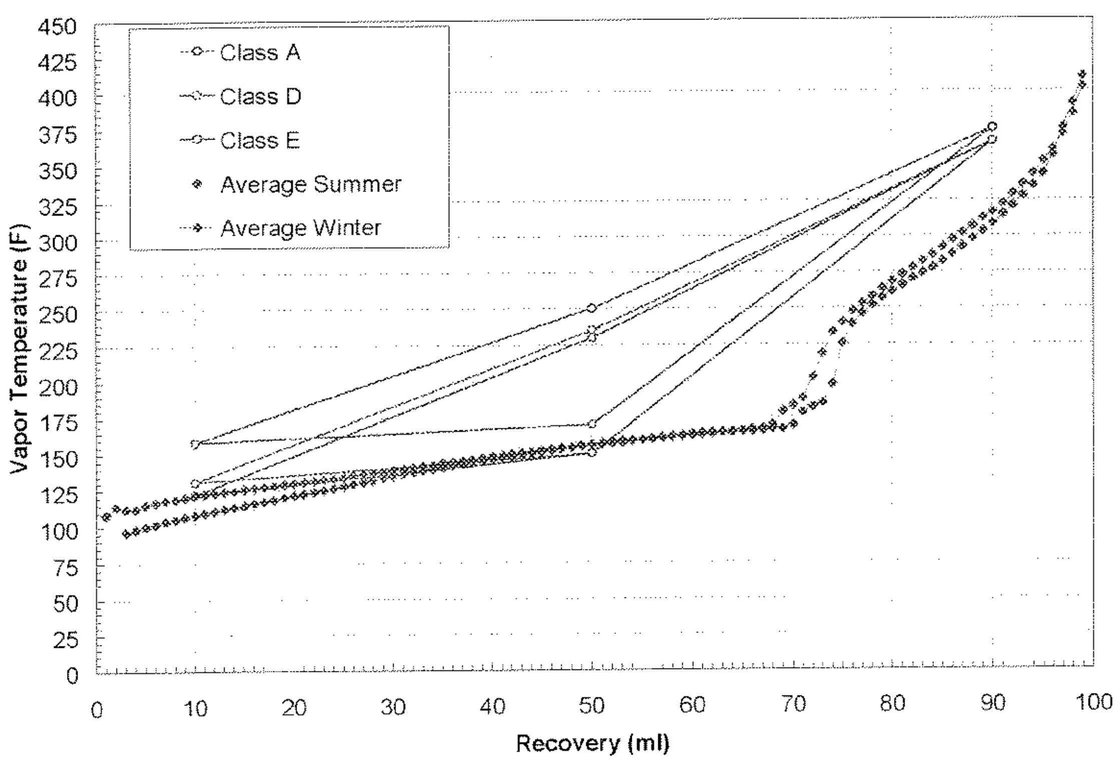

Figure 1b – Average Distillation Data for E20 Fuels. Also shown are ASTM limits for fuels Class A (summer, May 1 – September 15), Class D (fall, spring, September 16 – November 15, March 16 - April 30), and Class E (winter, November 15 – March 15).

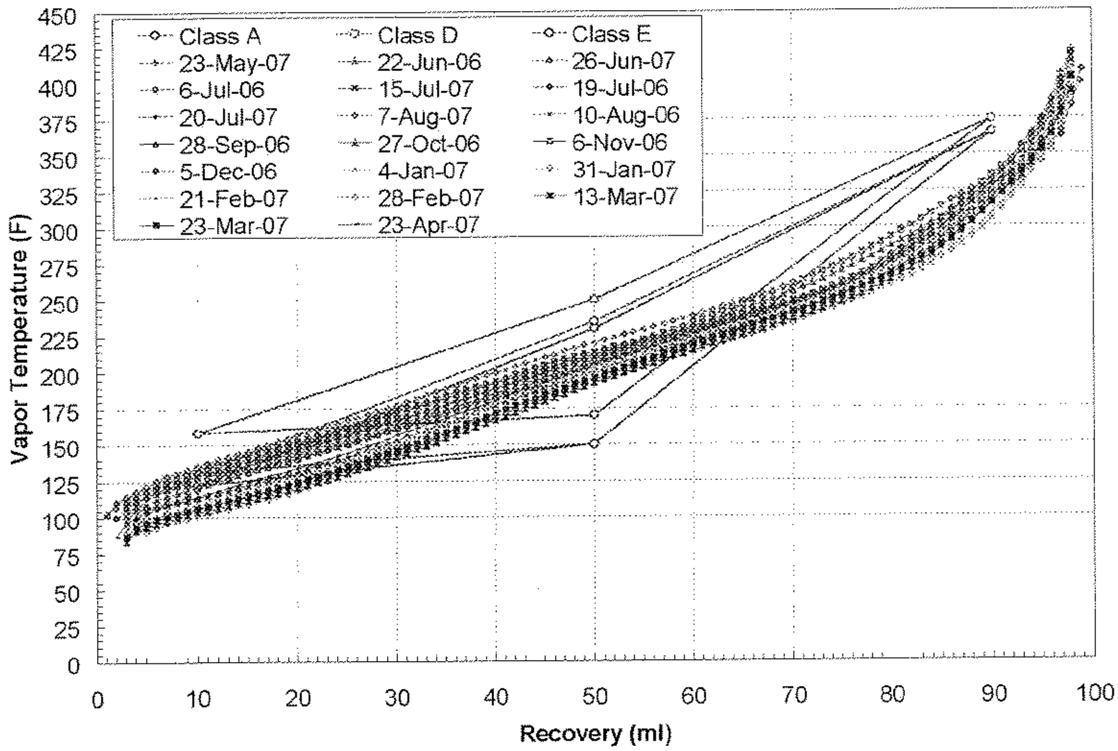

Figure 2a – Distillation Data for E0 Fuels. Summer fuels are plotted in warm colors, winter fuels in cool colors. Also shown are ASTM limits for fuels Class A (summer, May 1 – September 15), Class D (fall, spring, September 16 – November 15, March 16 - April 30), and Class E (winter, November 15 – March 15).

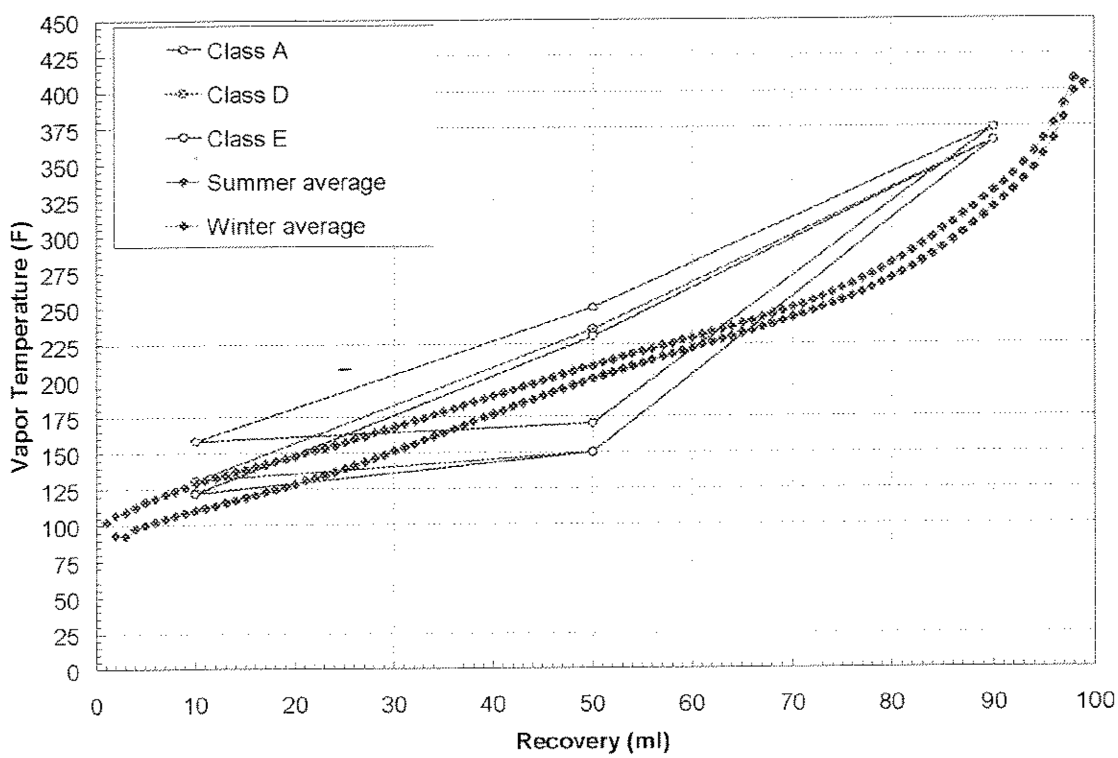

Figure 2b – Average Distillation Data for E0 Fuels. Also shown are ASTM limits for fuels Class A (summer, May 1 – September 15), Class D (fall, spring, September 16 – November 15, March 16 - April 30), and Class E (winter, November 15 – March 15).

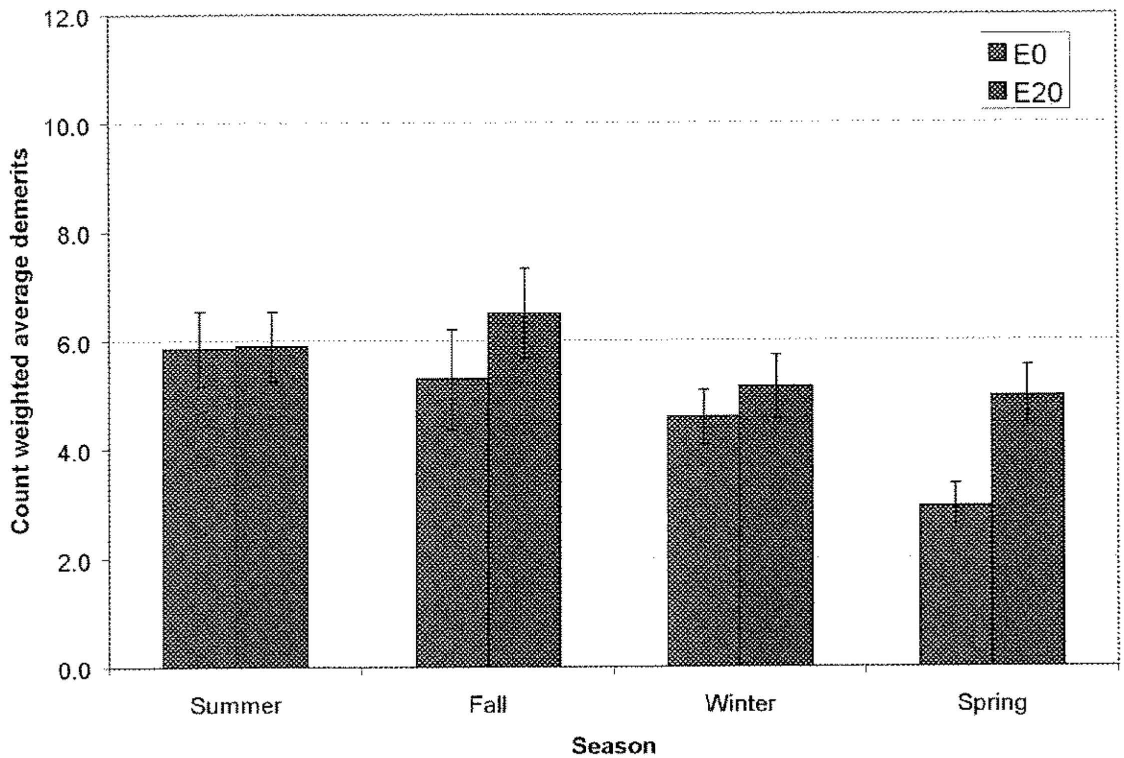

Figure 3 –Average Lay Driver Demerit Scores weighted by total number of reports. Error bars show 95% confidence intervals. Results shown only for paired vehicles both reporting. Differences between E0 and E20 reported for summer and winter seasons are not statistically different at a 95% confidence level.

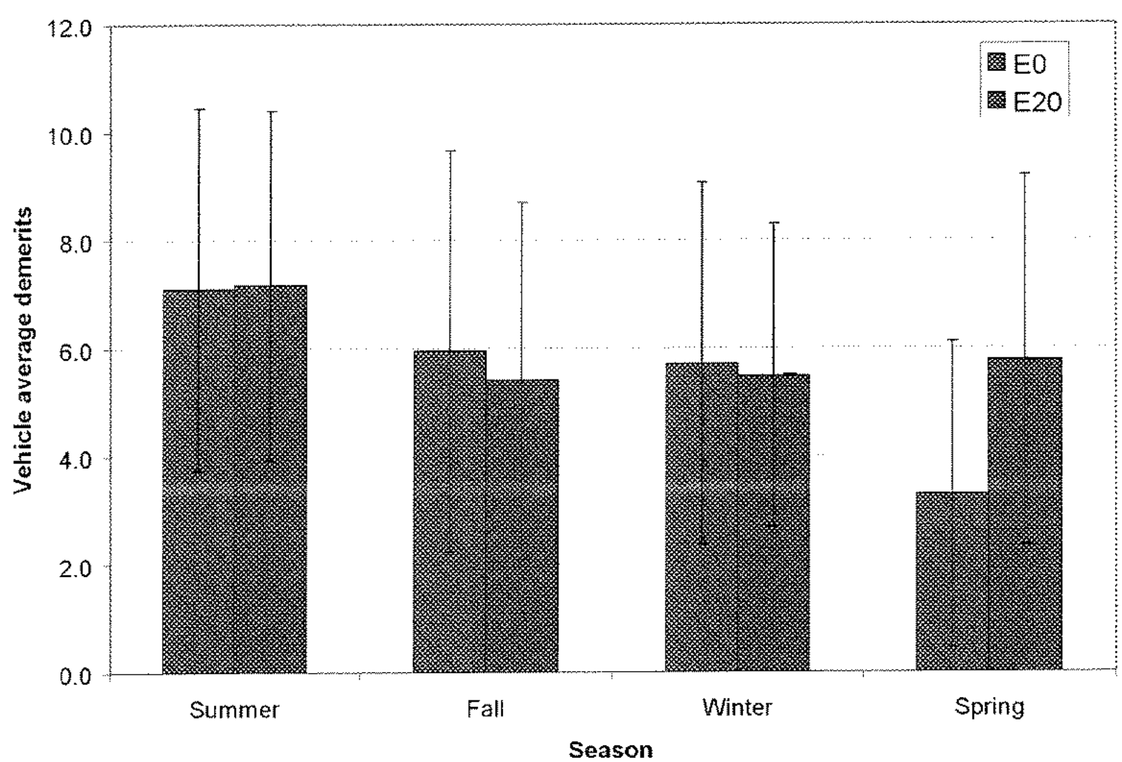

Figure 4 –Average Lay Driver Demerit Scores weighted by vehicle. Error bars show 95% confidence intervals. Results shown only for paired vehicles both reporting. None of the differences between E0 and E20 are statistically different at a 95% confidence level.

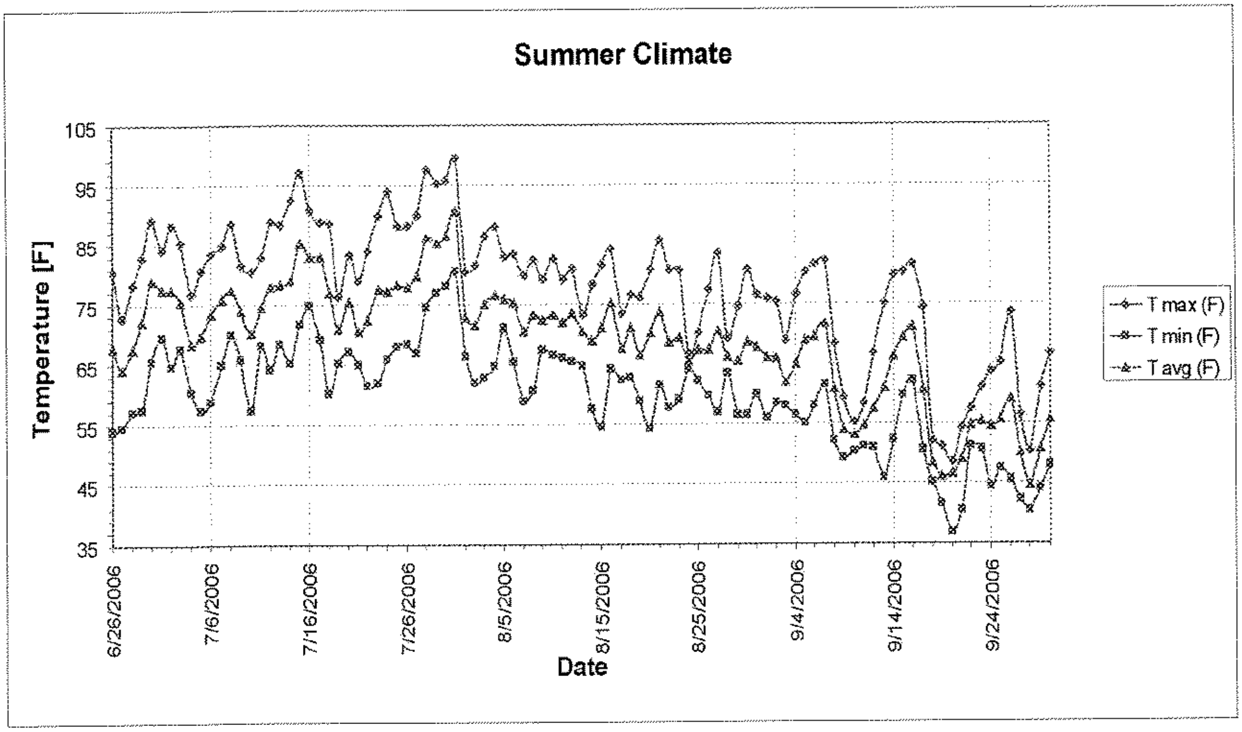

Figure 5a - Daily Temperature Data (recorded at St. Paul Campus), Summer Period

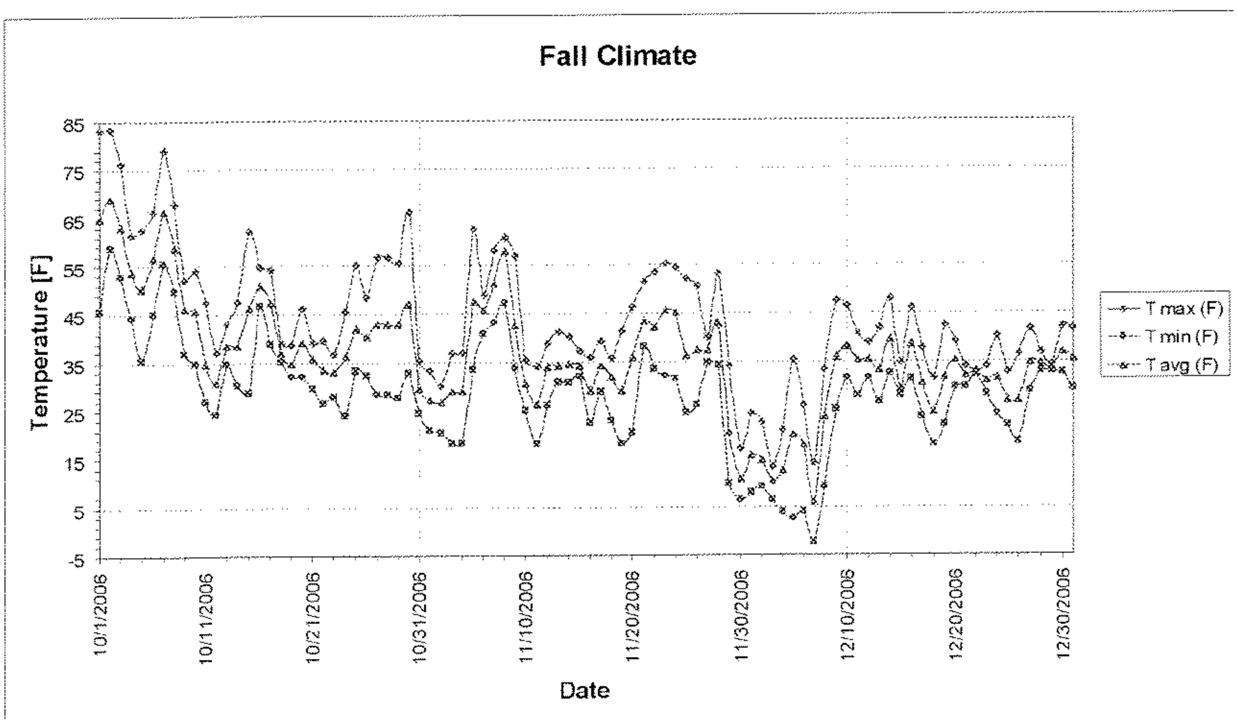

Figure 5b - Daily Temperature Data (recorded at St. Paul Campus), Fall Period

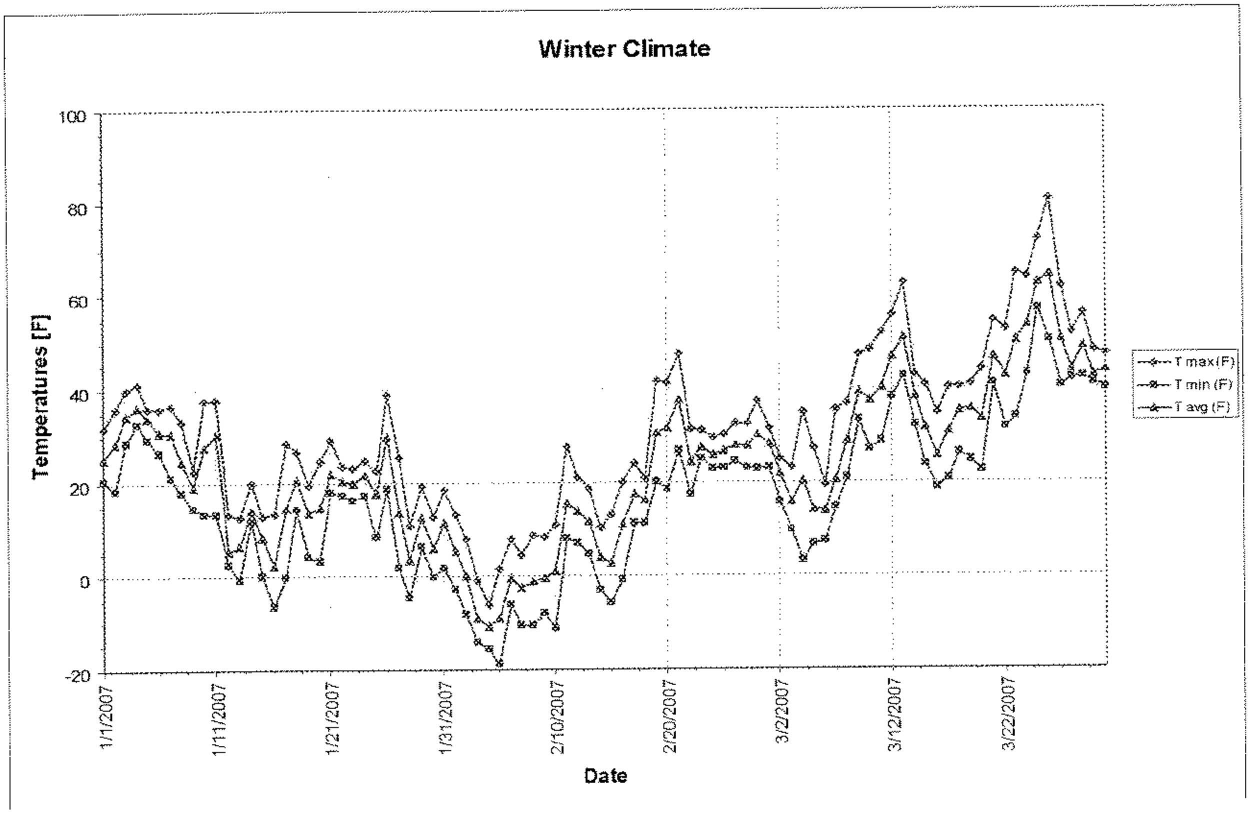

Figure 5c - Daily Temperature Data (recorded at St. Paul Campus), Winter Period

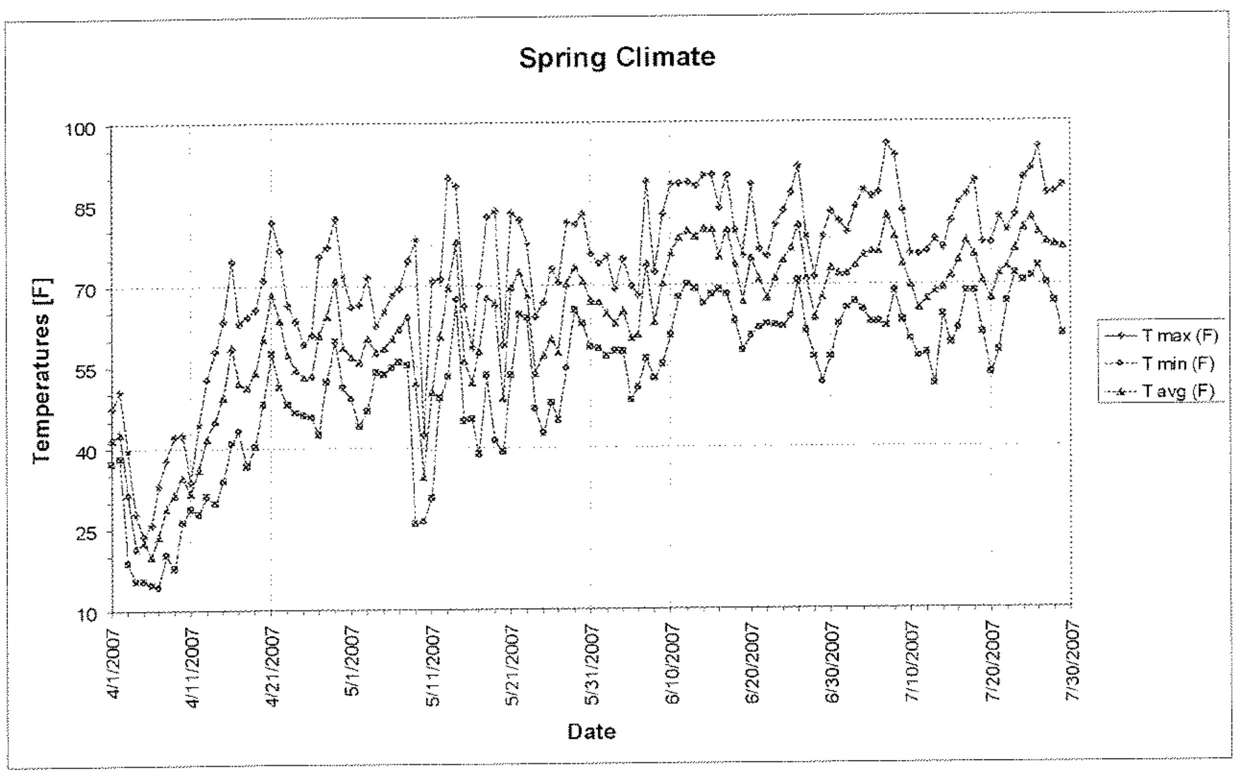

Figure 5d - Daily Temperature Data (recorded at St. Paul Campus), Spring Period

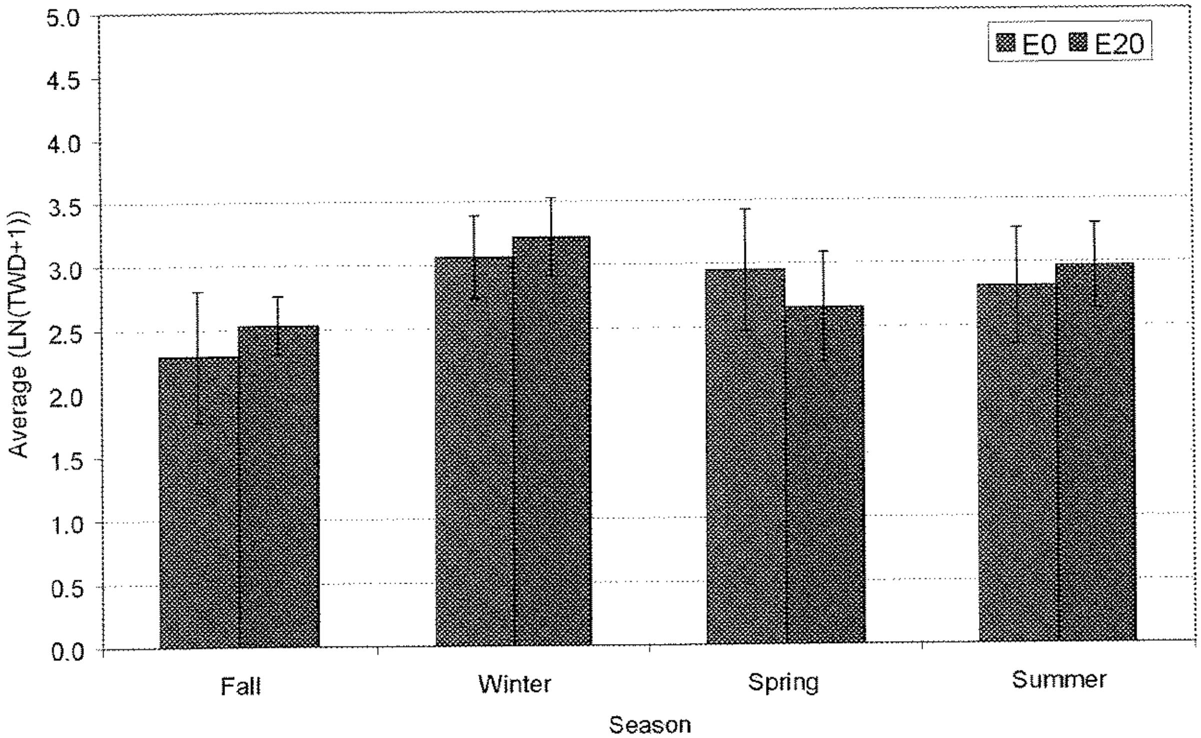

Figure 6a - Average Trained Raters' Log Transformed Weighted Average Demerits. Error bars show 95% confidence intervals. Results shown only for paired vehicles both reporting. None of the differences between E0 and E20 are statistically different at a 95% confidence level.

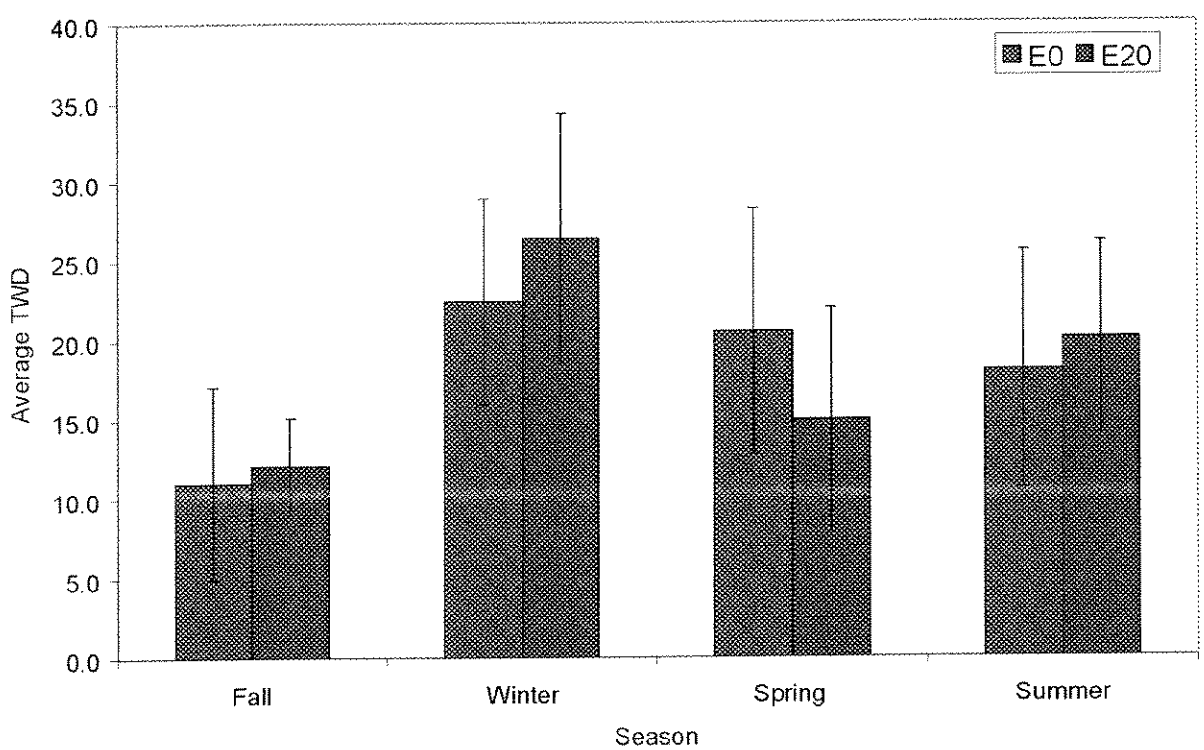

Figure 6b - Average Trained Raters' Weighted Average Demerits. Error bars show 95% confidence intervals. Results shown only for paired vehicles both reporting. None of the differences between E0 and E20 are statistically different at a 95% confidence level.

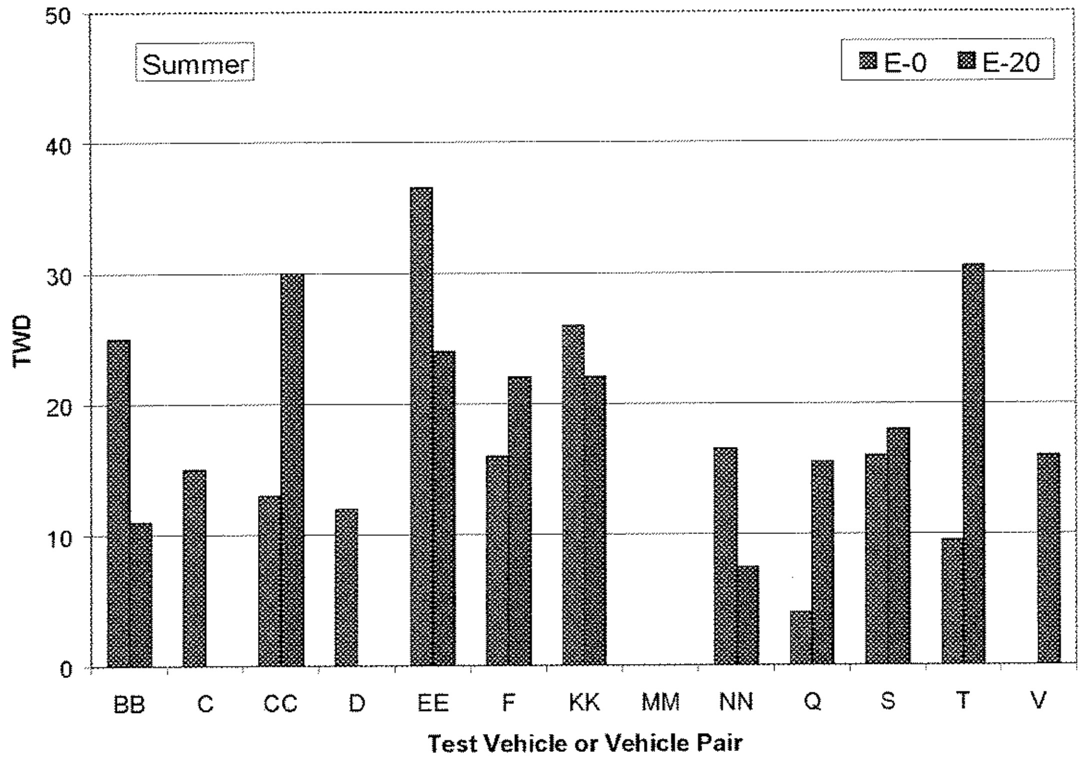

Figure 7a - Individual Vehicle Trained Rater Weighted Demerits for Summer Rating Session.
Both paired and unpaired vehicles shown.

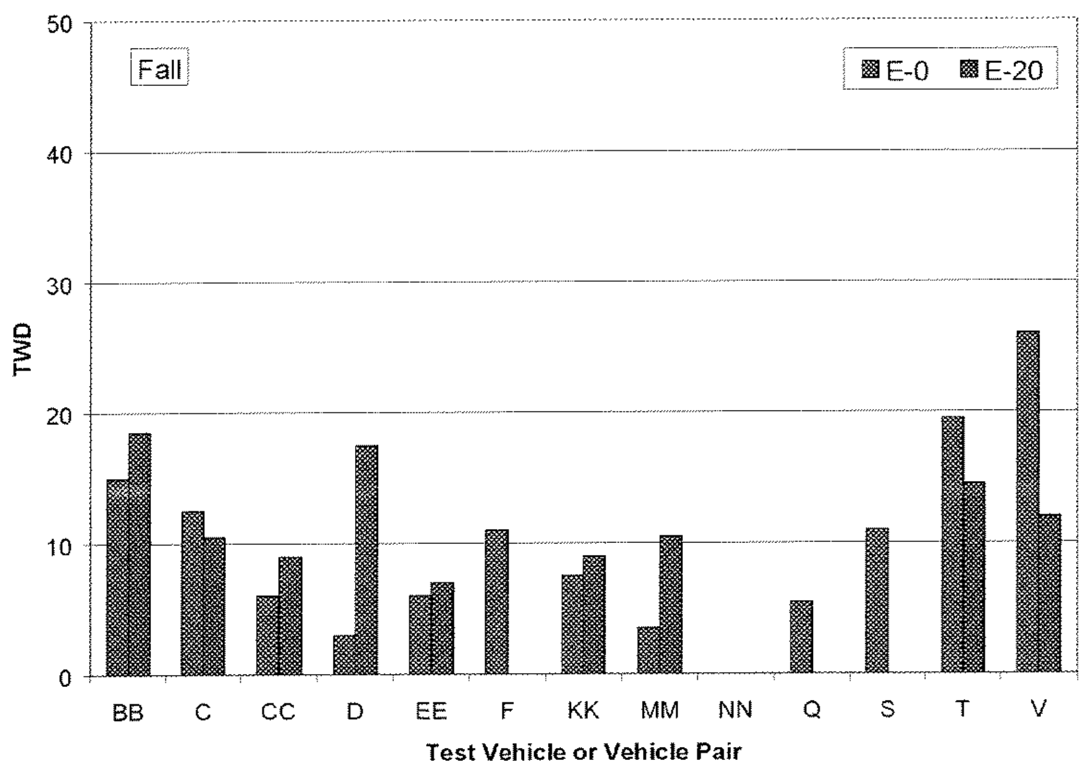

Figure 7b - Individual Vehicle Trained Rater Weighted Demerits for Fall Rating Session.
Both paired and unpaired vehicles shown.

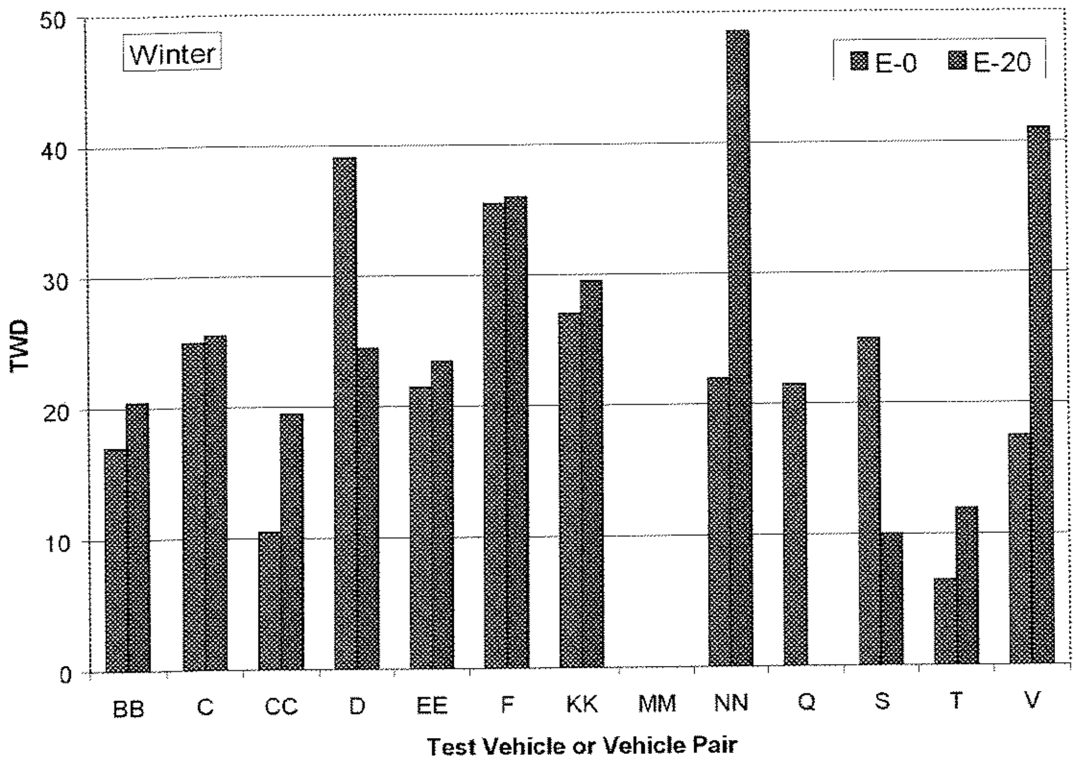

Figure 7c - Individual vehicle trained rater weighted demerits for winter rating session.
Both paired and unpaired vehicles shown.

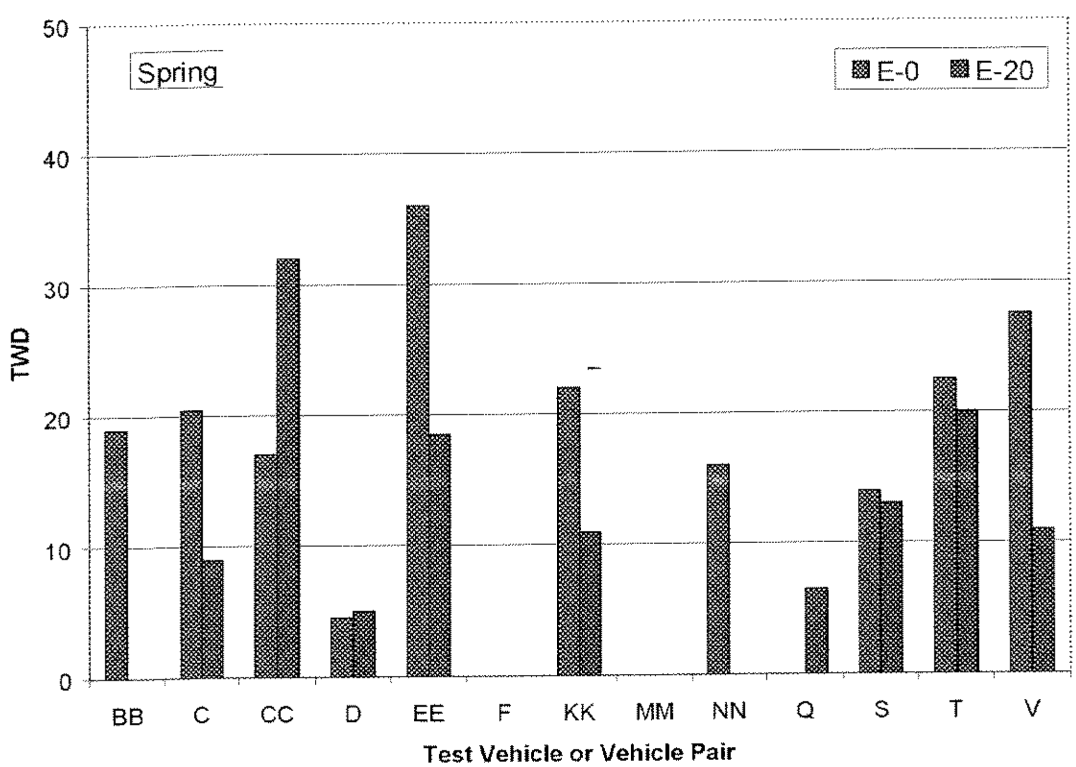

Figure 7d - Individual Vehicle Trained Rater Weighted Demerits for Spring Rating Session.
Both paired and unpaired vehicles shown.